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FINAL REPORT

Contract NASw-909

Rocket Study of Stellar X-Ray Emissions

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FINAL REPORT

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INTRODUCTION

The experiment described by this report was directed toward discovering, locating, and obtaining spectral information for, stellar x-ray sources at low galactic latitudes. A fundamental assumption, noted in the December 1960 proposal which lead to contract NAS 5-1174 and again in the May 1963 proposal which provided the basis for this contract, was that the brightest x-ray sources would be found to be of galactic origin and would be clustered near the galactic equator. This assumption has now been proven correct. Appended to this report are: a) three publications from reduction of data from the two previous rocket flights, supported by contract NAS 5-1174, which provided much of the scientific basis for the present experiment (although the articles themselves resulted from efforts made after termination of that contract) and b) two articles containing the final results of the first of the two ACS-rocket flights supported by this contract, NASw-909.

A brief and preliminary estimate of the results of the second ACS-rocket flight is also contained in this report. The observations to be carried out emphasized investigation of x-ray fluxes between 1A and 40A, and obtaining experience with two previously unused measurement techniques believed necessary for successful design of several satellite experiments. As most of the pertinent details of the new techniques will be given in the final report to contract NASw-917, the present report is restricted to a summary of the well-understood x-ray source information plus conclusions and recommendations based on all flight data.

EXPERIMENTAL METHOD

The general procedure for making observations was to utilize rocket-borne detectors to slowly scan a particular portion of sky. Each rocket was equipped with several completely independent visible-starlight photometers and x-ray detectors. The Sounding Rocket Branch of the Goddard Space Flight Center kindly altered the Aerobee's ACS to permit slowly rotating a rocket about one of its inertial axes. The majority of the maneuvers were carried out in roll for the first rocket and in yaw for the second rocket. This maneuvering caused the detectors to scan previously prescribed swathes of sky. By properly correlating the times of occurrence of the signals from at least one starlight sensor and two or more x-ray detectors, it was possible to determine the location on the celestial sphere of each x-ray source.

As shown in Figure 1, a large portion of the available cross-section of the first rocket was utilized for counter aperture. All of the x-ray counters were sealed units and fairly direct descendants of similar proportional counters flown on two previous rocket flights (under contract NAS 5-1174). The three larger-area counters were equipped with 5-mil beryllium windows while the two smaller-area counters possessed 1/2-mil aluminum windows. The fields of view of the different counters were prescribed by the cellular collimators which were removed from the rocket when the picture was taken. When the ACS programmer was set up, the existence of only two x-ray sources had been reliably established (one in Scorpius and one in the Crab Nebula). The observing program was chosen to provide two slow scans near the galactic equator in such a manner as to traverse a) the bright source in Scorpius discovered by Giacconi et al (Phys. Rev. Letters 9, 439, 1962) b) the region containing the galactic center, and c) the two highest count rate (non horizon-related) regions observed on the two preceding rocket flights and thought to possibly be x-ray sources. Some of the background roblems noted during these "two preceding" flights are commented on in Appendices A and B, while the nature of the horizon-associated signals are considered in the articles given as Appendices B and C. The two possible night sky x-ray source regions are discussed in Appendices A, C, and D, the latter being brief remarks about the results of the first ACS-flight as made at the Second Texas Symposium on Relativistic Astrophysics. A more complete description of the results of the first ACS-flight is given in Appendix E.

The payload for the second ACS-rocket flight is shown in Figure 2. X-ray proportional counters mounted to look out the side of the rocket were sealed beryllium window units similar to those used on the preceding flight. A bare photocathode detector with a channeltron multiplier, shown partly fabricated in Figure 3, was also mounted so as to look out the side of the rocket. Three separate flow proportional counters with thin mylar windows were used to look out the aperture formed by ejecting the nose of the rocket. Two of these counters, and the partly assembled Venetian blind x-ray collector used with them, are shown in Figure 4. Because of the restricted field of view of the x-ray detection systems mounted in the forward end of the compartment, the ACS was supplemented with a roll stabilized platform to increase the probability of scanning over the previously observed x-ray sources. The observing program called for two slow scans of the brightest x-ray source in Cygnus with the Venetian blind (and other mylar window) counters, at the same time that the side-mounted detectors swept over the sources at low galactic longitude. A final scan was to be made of galactic latitudes near $\ell^{II} = 0$ in order to obtain precise latitudes (to ~ 5 min of arc) for several of the x-ray sources. By observing some of the same sources seen on the first ACS-flight, information about time variations of x-ray source strength was to be secured.

Although only preliminary results of the most recent flight now exist, at least qualitative spectral information (for photon energies greater than about 2 keV) and some position information (possibly with $\pm$ 30 min of arc accuracy) may be derived for some five x-ray sources at low galactic longitudes. Source fluxes in the neighborhood of 15A were not secured because of a pair of ACS problems which resulted in

a) both of the Cygnus sources passing outside the fields of view of the nose counters and b) failure to carry out the final scan in latitude. As the rocket was not equipped with a parachute, precautions were taken to remove the tail fins prior to re-entry in order to insure a tumbling vehicle and improve the chance of successful recovery of film from an aspect camera. The film was recovered in usable form, even though the film casette had been broken open. A considerable effort must still occur before a reliable or detailed account of the flight results is available.

RESULTS AND CONCLUSIONS

a. Most of the nine x-ray sources observed from the first ACS-equipped rocket lie at low galactic longitudes, and so the majority of these sources are believed to lie within the Galaxy.

b. Of the two possible x-ray sources located with the aid of an earlier contract (NAS 5-1174), the source in Cepheus has been proven to be spurious while the source thought to be in Cygnus was indeed found where anticipated.

c. More than one parameter is required to describe the spectral distribution in the 1 to 20 keV range of the brightest x-ray source in Scorpius.

d. X-ray emission locations are still too poorly defined to permit their being associated with known optical or radio sources. However, significant x-ray fluxes were not observed from the Kepler and Tycho supernovae, or from Cas A or Cyg A.

e. A fairly isotropic flux of x-rays exists in addition to the x-rays associated with discrete sources. Although the spectrum appears to fall off steeply with increasing photon energy, in the 4-8-keV energy interval the flux is at least three photons cm^{-2} sec^{-1} $ster^{-1}$. At somewhat higher energies, the dominance of atmospheric x-rays first noted on the March 1963 rocket flight (cf. Appendix C) was confirmed by the first ACS-rocket flight. Because of these atmospheric effects, no really definitive limit can be derived from the data for this diffuse (background) component at energies above 8 keV.

f. On the second ACS-rocket flight, several photometers were blinded by a glow apparently associated with the gas exhausted by operation of the ACS. Therefore, special precautions must be taken to protect stellar-aspect photometers during flight of ACS-equipped rockets in sunlight.

g. Although at least a northern (and possibly a southern) horizon brightening effect seems to have been observed on the September 1962 and March 1963 rocket flights from Wallops Island, Virginia, no horizon effects were found on the October 1964 flight from White Sands, New Mexico. It may be worth noting that the northern auroral zone cannot be easily viewed from an Aerobee launched at White Sands, although that zone is visible from a Virginia-launched rocket. A north-south asymmetry noted by Hayakawa, Matsuoka, and

Yamashita (1965, private communication), may be further evidence for some sort of horizon effect, or of an effect associated with trapped particles.

INFERENCES

The fact that the majority of the observed x-ray sources lie within the Galaxy can serve as a basis for evaluating the feasibility of obtaining morphological information for some extended nearby systems. While a similar evaluation was presented in the November 1963 report to contract NAS 5-1174, the current improved understanding of attainable detection sensitivities makes a reappraisal of the situation appropriate. This general type of investigation seems worth attempting, as success might help to determine whether the brighter x-ray sources belong to a particular stellar population. One manner of performing the evaluation is to determine the minimum number of x-ray sources which must simultaneously lie within a single field of view in order to produce a signal three standard deviations above background. Assumptions concerning the distance of the presently known sources, the existence of similar sources in the system being investigated, and the sensitivities of future detection systems must be made. Table 1 contains the results of such an evalution, the standard x-ray source flux having been assumed equal to that of Ser XR-1 which is near to being or actually is the faintest of the presently observed sources. When the detection threshold corresponds to between approximately 0.5 and 2 such sources, it is reasonable to hope that at least some morphological information might be obtained. This seems to follow from the fact that the apparent brightness of the Ser XR-1 source is actually only 1/20th to 1/100th that of the brightest non-solar source yet detected. On these grounds, at least the Magellanic clouds may be capable of yielding morphological information if examined with a detector whose diameter could just be fitted within the OAO.

Table 1 Quantity of sources in external systems that must lie within a detector's field of view in order to produce a statistically significant signal. Each source is assumed to produce a flux similar to that of the weakest local source that has yet been observed from a slowly scanning Aerobee rocket (the Ser XR-1 source that may have been seen from Aerobee 4.120 required a detection sensitivity of 0.2 photons cm^{-2} sec^{-1}).

Vehicle, and (Detection Sensitivity in Photons cm^{-2} sec^{-1})	System	Distance (kpc)	Quantity of Sources	
			Assuming Ser XR-1 at 1 kpc	Assuming Ser XR-1 at 5 kpc
Maximum area, OAO-diameter Detector (10^{-4})	LMC	42	4	0.2
	M31	440	400	20
	M33	460	400	20
Successor to OAO Detector (10^{-5})	M31	440	40	2
	M81	1.3×10^3	500	20

The steeply falling and not simple spectral distribution of the Sco XR-1 source suggests that detailed study of x-ray spectra may be rewarding. The spectrum of the diffuse (or background) flux also falls off rapidly with increasing photon energy. However, it is impossible at this time to reliably predict the amount of structure in x-ray spectra as no sufficiently detailed observation has yet been attempted.

RECOMMENDATIONS

While all recommendations in the November 1963 final report to contract NAS 5-1174 are still valid, they are not repeated here. Instead rather more specific and less sweeping suggestions are made:

a. Efforts should be devoted to obtaining precise locations (say to within a few minutes of arc) of as many x-ray sources as possible.

b. Measurement of the gross spectral distribution of the softer x-rays (between energies of about 0.1 and 3 keV), and determination of the angular extent of x-ray sources, should both be pursued.

c. For the diffuse x-ray flux, the gross variation of flux level as a function of galactic coordinates and the gross shape of the spectrum in the low energy region should be determined.

d. Source spectra and polarization should both be examined with high resolution equipments.

e. Balloon experimentation at the higher ($\gtrsim$ 15 keV) photon energies should be strongly encouraged, with emphasis being given to obtaining x-ray source information as well as to training personnel for space astronomy in general.

f. Because detectors with bare photocathodes and image intensifiers probably must be used in some part of at least a few of the x-ray systems needed for the above efforts, the noise problems associated with this type of flight instrumentation should be evaluated by in situ measurements whenever convenient.

g. When NASA provides an ACS-equipped rocket to an experimenter, at least 8 continuous channels of 60 cps response telemetry should be reserved for use with the ACS in order to obtain a fairly complete diagnosis of its operation.

h. The first uncommitted OAO should be set aside for x-ray experiments leading to high spectral resolution, high angular resolution, and polarization information of previously known x-ray sources, and high detection sensitivity of restricted and previously source-free regions. Other satellite space should be made available for the highest possible sensitivity few-color photometry survey of the entire celestial sphere.

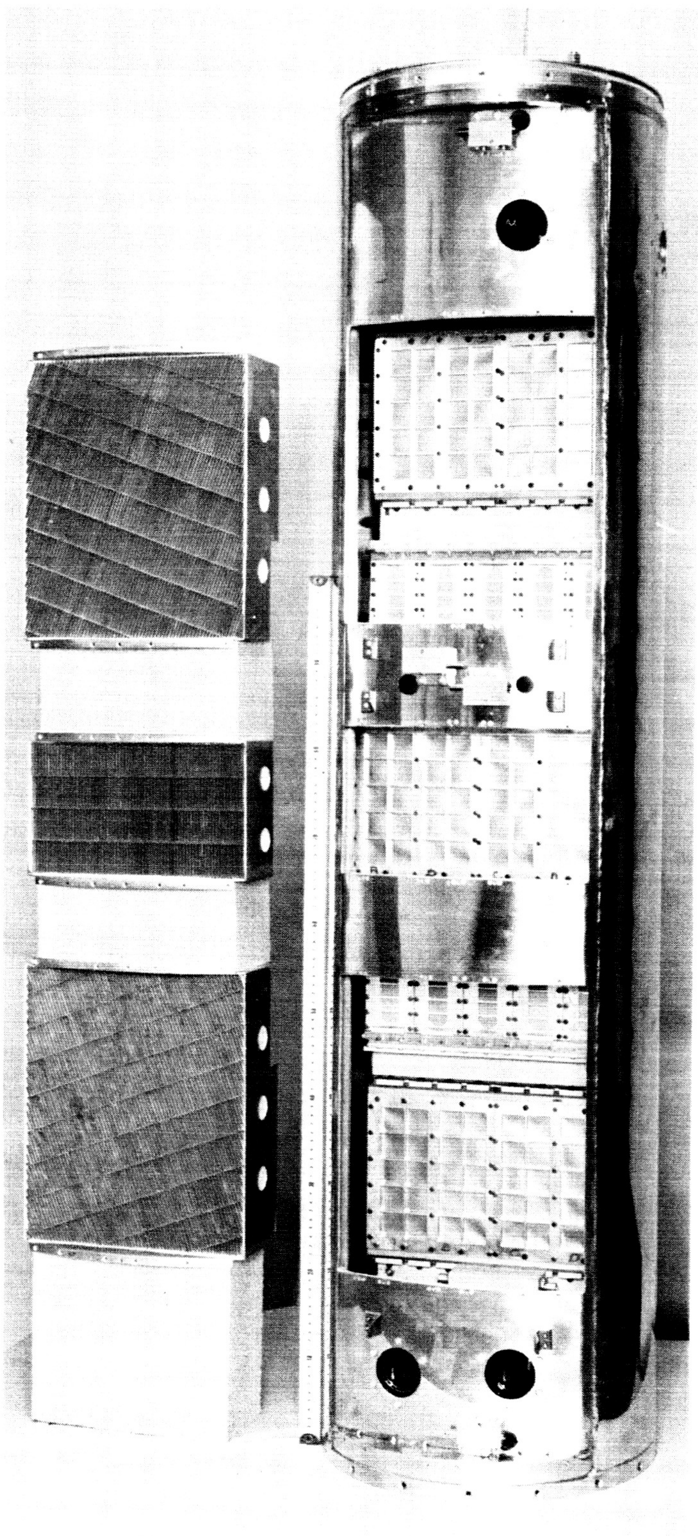

Fig. 1 View into Aerobee 4.120 instrument compartment. The presence of three starlight sensing photometers is indicated by the circular black discs (two near the base and one near the top of the compartment). The majority of the aperture was taken up by three beryllium and two aluminum window gas-proportional counters which viewed x-ray sources through the cellular aluminum collimators shown at the left of the figure. Scintillator units for anti-coincidence work lay underneath the x-ray detectors and so are not visible in this view.

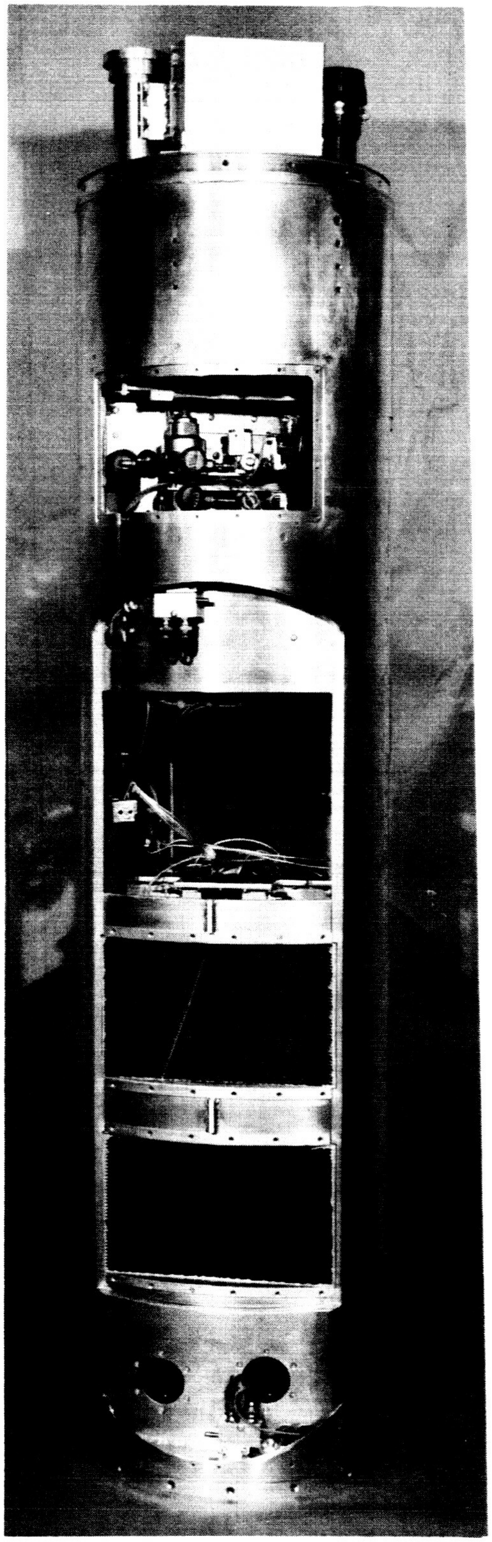

Fig. 2 Aerobee 4.121 instrumentation prior to installation of the Ventian blind gas counter assembly and the bare photocathode unit, which together fill the void shown near the center of the rocket compartment. A pair of starlight sensors and beryllium window x-ray detectors and the bare photocathode detector were oriented to look out the side of the rocket. A Venetian blind system, a mylar window x-ray detector, a starlight sensor and a camera were located so as to view the sky through the forward end of the rocket.

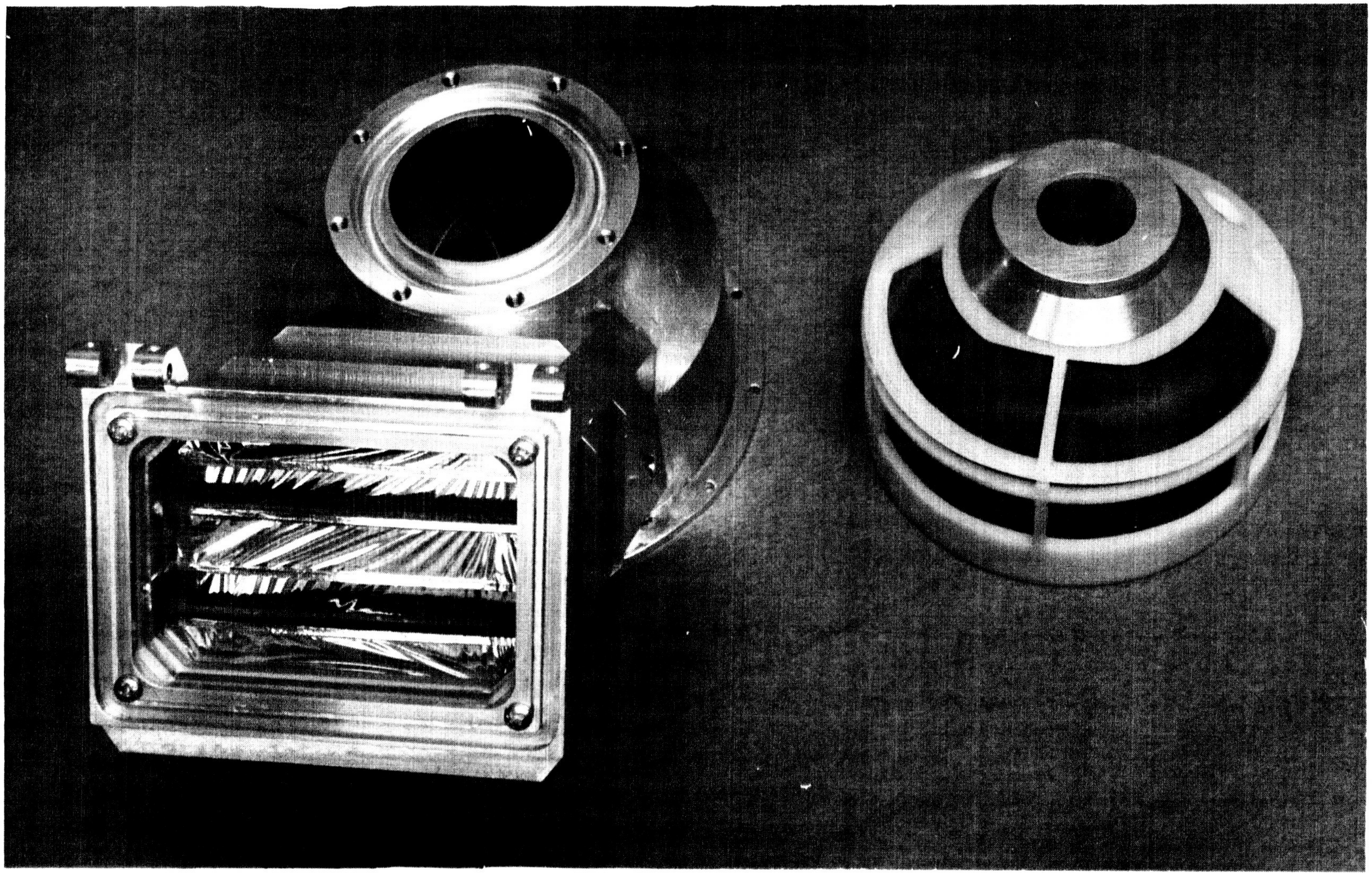

Fig. 3 View of partly assembled components of the bare photocathode detector. X-rays entered the detector through the rectangular gridded-aperture at the left of the figure. The grids were used to isolate the photocathode from the plasma surrounding the detector. After filtering by the aluminized mylar films, also shown at the left of the figure, x-rays were allowed to enter the electrostatic focusing structure at the right of the figure and then shine on a SrF_2 photocathode at the base of that structure. The resultant photoelectrons were accelerated to the entrance of a channeltron multiplier situated at the apex of the focusing structure.

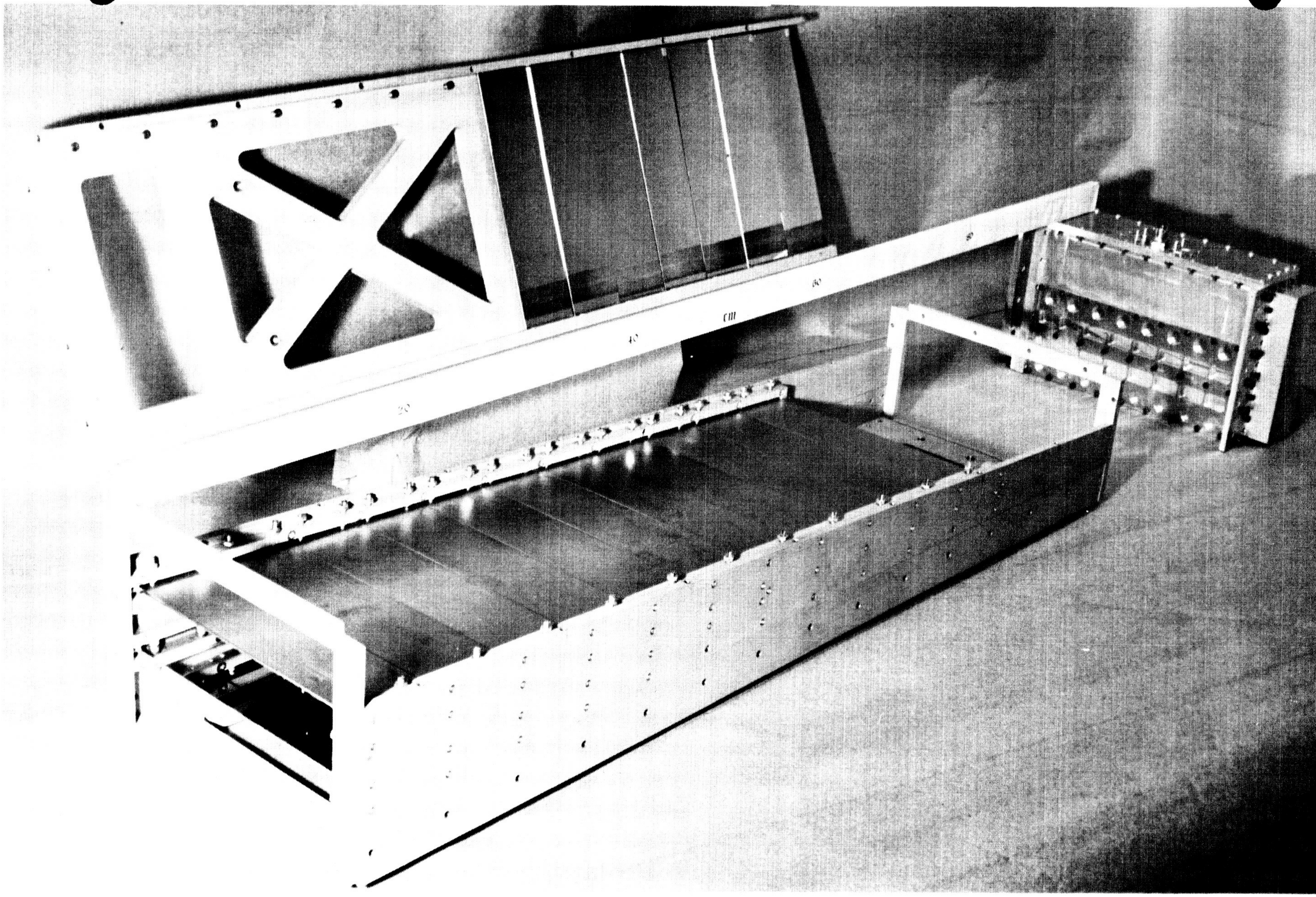

Fig. 4 A partly assembled dual Venetian blind system is shown above. Two of the four arrays of Venetian blind slats are in place, while a third incomplete array appears near the top of the figure. Various reflections help to clearly outline some of the edges of individual slats in the third array. The two mylar window proportional counters are shown in the assembly positioned at the end of the meter stick, in the Venetian blind's focal plane.

APPENDICES

(Published articles)

A. The Astrophysical Journal, 140, 821-823, 1964

B. Nature, 204, 982-983, 1964

C. Annales d' Astrophysique 27, 809 - 812, 1964

and

IAU Symposium No. 23, ed. J.-L. Steinberg, UNESCO, 1965, p. 241-244

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Vol. 140, No. 2, August 15, 1964

REPLY TO LETTER OF STUART BOWYER

The preceding letter by Bowyer is concerned with a paper by Fisher and Meyerott (1964; hereinafter referred to as "Reference 1"). The essential point of Bowyer's alternate explanation is that the source locations suggested in Reference 1 may be due in fact to random background fluctuations above an improperly chosen low-average background value. The difficulty of properly interpreting the low counting rates observed in Reference 1 has been a continuing concern to the undersigned, and for this reason alternate methods of statistical analysis have been and still are being pursued. Some preliminary results of these revised data handling procedures (applied to data of each flight) were presented at the Meeting on Neutron Stars and Celestial X-Ray Sources held in New York on March 20, 1964. Although the results of this improved analysis are not yet complete, it is apparent that the tentative nature of the conclusions reached in Reference 1 must be emphasized, and that Bowyer's alternate interpretation must be considered seriously.

The large amount of sky area found to be one standard deviation (1σ) above background in a plot for any one of the three Aerobee 4.70 energy intervals of Reference 1 resulted primarily from our use of the Gaussian error approximation in constructing the isophote plots. The high-count regions for individual energy intervals of Aerobee 4.69

data appeared large in area because of a combination of the very low background used and the Gaussian error analysis. The difficulty in handling properly the few counts available in each energy-time interval of Reference 1 was ameliorated by increasing the number of events in each element of the isophote plots for each flight by combining data from pairs of resolution regions, from one or more counters and/or from two of the three original energy intervals.

The results of the analysis of Aerobee 4.69 data must be considered unreliable at this time for two reasons: (1) the low background values used for the published isophote plots, and (2) the incomplete allowance made for transient count-rate effects. Original examination of this data revealed unquestionably statistically significent fluctuations of count rate with time. The transient efforts occurred over short (< 1 sec) to long (> 20 sec) time intervals and were not correlated with celestial sphere position. Use of a more sensitive data-reduction method has revealed several additional seemingly real transients. These were not previously recognized, and are probably terrestrially associated. Their influence should have been excluded from the Reference 1 isophote plots but was not. Similar transients have not been detected in the Aerobee 4.70 data. These comments are sufficient to render the published results and interpretation of the Aerobee 4.69 data inconclusive.

To determine whether the Aerobee 4.70 high-count regions arose from selection of an improperly low background, randomly selected portions of the original isophote plots were rederived. A background rate equal to the total counts (when the detectors were pointed away from the Earth) divided by the total observing time for these counts was used, and is identical to that suggested by Bowyer. Substantially the same high-count regions (as in the published analysis) appeared from this rederivation process. However, since the Aerobee 4.69 data cannot provide reliable confirming evidence at this time, due regard for the low level of statistical significance of the Aerobee 4.70 high-count regions forces the conclusion that they do not in themselves provide convincing evidence for real sources.

Since the derivation of the published results of Aerobee 4.70, a more accurate aspect solution of the rocket's flight has been obtained, permitting the inclusion of lower photon-energy data for two more scans of the sky previously withheld due to the possibility of atmospheric absorption effects. The preliminary results of this analysis were presented at the Meeting on Neutron Stars and Celestial X-Ray Sources. The net result of the somewhat more sophisticated methods of analysis, using the same background as suggested by Bowyer, is that we are left with but one high-count region that is considered as suggestive of a possible night-sky source. This region occurs near the Reference 1 location of ($\alpha = 23^{\mathrm{h}}$, $\delta = +79°$). A noticeably high count rate was observed on five of the seven successive scans that went over this region. For photons in the 0.5–8 keV energy range, the total of twenty-five counts detected should be compared to an average background of fourteen counts. The signal is then about 3σ above background and is suggestive because it appears in a majority of the total scans over the region. The probability of observing a random fluctuation of this nature in the night sky is estimated to be less than 20 per cent.

Bowyer, Byram, Chubb, and Friedman (1964) are correct in pointing out that a flux as low as that attribited by them to the Crab Nebula would have produced no more than one event in a minimum resolution region in the 4–8 keV energy range for one scan by an Aerobee 4.70 detector. Counter detection sensitivity should properly be described as a function of geometric aperture, observation time per scan, detection efficiency, solid angle, background, and number of scans of a given region. The product of the first two of these quantities for the Naval Research Laboratory detector in the 4–8 keV range is conservatively estimated as no more than $\sim 5x$ larger than for the K-B-90 detector on Aerobee 4.70, as opposed to the factor of 13 which applies to the geometric aperture alone. As stated in Reference 1, our failure to associate a high-count region with the Crab

Nebula was primarily based on the combined data for the 4–8 keV and 12–20 keV energy intervals. Because no significant evidence for events in the 8–12 keV range (and so by inference in the 12–20 keV range) was recorded by the NRL experiment, our failure to observe the Crab Nebula may be readily traceable to either our lower sensitivity or to a combination of lower sensitivity and examination of a different and larger energy interval.

To summarize the above, the published Aerobee 4.70 results are fundamentally correct, but the statistical significance of the high-count regions is low. The confirmatory evidence which had been derived from the Aerobee 4.69 data is now considered to be unreliable. Ultimately, the Aerobee 4.69 data may prove useful only as a study of statistically significant terrestrial effects. According to the authors' standards given in Reference 1, data from a single flight exhibiting a high count region even three standard deviations above background are insufficient to establish the reality of that region. Therefore, the conclusions reached in Reference 1 (although affirmed by other data-reduction procedures) must be considered as tentative and suggestive only.

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Upper Limit to Jupiter's X-ray Flux on September 30, 1962

DURING a search for celestial sources of X-ray emission, several opportunities arose to detect X-rays associated with Jupiter's radiation belts. The observations presented here were obtained from three successive scans of Jupiter made by a proportional counter flown on an *Aerobee* rocket launched from Wallops Island, Virginia. Although significant X-ray fluxes (which were time-dependent and apparently associated with or led to horizon effects) were observed, no X-ray flux from Jupiter was detected. The observations given in Fig. 1 below led to a conservative upper limit of $2 \cdot 4 \times 10^{-8}$ ergs/cm^2 sec for the flux of 4–8 keV (3–1·5 Å) photons from Jupiter between 0603 U.T. and 0605 U.T. on September 30, 1962.

The proportional counter employed had an effective aperture of 8 cm^2 provided by a beryllium window 0·005 in. thick set into the side of the counter. A sweeping magnet prevented electrons less energetic than 50 keV from impinging on the counter window. Collimation was provided by a simple aluminium baffle used to fix the field of view at (maximum widths of) 60° × 85°. The rocket rolled at a rate of 15°/sec and precessed in such a manner that the 60° dimension of the field of view scanned past Jupiter on three successive occasions early in the flight. Results related to galactic X-ray sources and details concerning instrumentation may be found in Fisher and Meyerott[1], and Fisher, Meyerott, Grench, Nobles and Reagan[2], respectively.

Fig. 1 gives the detector (labelled *K*–O–115) counting rate in two adjacent energy intervals for three complete rolls of the rocket as a function of time. A universal time of 0603 corresponds approximately to 100 sec after launching the rocket. The detector's field of view was inclined at an angle of 65° with respect to the rocket's nose, which was tipped down to the east by some 30° with respect to local vertical. As a result, the centre of the counter's field of view scanned along a path which rose above the northern horizon, passed approximately midway (near Cygnus) between zenith and the western horizon, descended to the southern horizon, and then scanned from south to north along the eastern horizon. The shaded areas in Fig. 1 separate regions in which the long (85°) dimension of the counter's field of view was completely above or below the rocket's horizontal horizon. Corrections made for counter dead time are such that instantaneous counting rates, for the combined energy intervals, greater than some 20 counts/cm^2 sec are not very precisely known. The 4–8 keV (3–1·5 Å) background of 9 photons/cm^2 sec (7·2 counts/cm^2 sec) was found by averaging data from the first two of the three available scans when the (85°) long central field of view dimension was completely above the horizon. The third scan was not used because Jupiter fell so near the edge of the counter's field of view that the detection sensitivity was only one-half that of the preceding two scans. Allowing for the 2 sec/scan that Jupiter fell within the counter's field of view at greater than 50 per cent detection efficiency, the upper limit for the 4–8 keV 3—1·5 Å) flux from Jupiter is 2·4 photons/cm² sec. This value corresponds to a signal three standard deviations above the average background level. Warwick[3] has

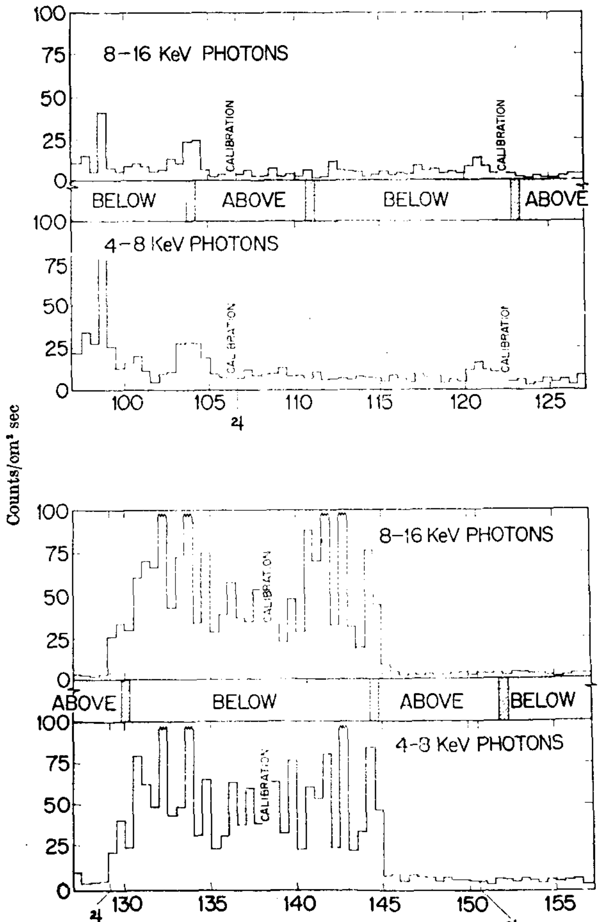

Fig. 1. Variation with time after launch of detector count rate in two adjacent energy-intervals

estimated that Jupiter's X-ray flux might be of the order of 1/5,000 of the limit quoted here.

Further inspection of Fig. 1 establishes the fact that, during this part of the flight, instantaneous count rates significantly above the night sky background only occur when the detector's field of view includes some portion of the horizontal horizon. The complete northern auroral zone could be observed at one instant by the detector and measurements in that direction appear to produce the highest counting rate found during the whole flight. The time sequence given in the figure indicates a weak source near 104 sec of flight time, which was not present one roll later near 122 sec. However, at 145 sec, after the next complete revolution of the rocket, a source intense enough to jam the counter's electronics was found at approximately the same azimuth as the 104-sec source. The latest revolution indicates a source or sources extending along the whole eastern horizon, although the detected X-ray flux appeared to be most intense near the northern and southern extremities of the eastern horizon. Because of the rocket's precession, maximum sensitivity to the northern horizon source occurs at times separated by less than the 22-sec roll period of the rocket. No attempt has been made to associate the observed X-rays with the standard indicators of non-local ionospheric or auroral activity.

While significant and time-varying horizon related X-ray sources were found, no X-ray flux from Jupiter was observed. The upper limit to the 4–8 keV (3–1·5 Å) photon flux for the particular epoch investigated was 2·4 photons/cm^2 sec.

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OBSERVATIONAL RESULT ON X-RAYS (*) (V-3)

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Résumé. — *On donne les résultats finaux de la recherche de sources de rayons X mous dans le ciel nocturne (20 mars 1963). Une seule région du Ciel a fourni un signal supérieur à 2,5 à 3 fois l'écart statistique le plus probable alors que la probabilité d'observer un écart statistique fortuit de cet ordre est de 0,2. La région est située à* $\alpha = 23\ h\ 40\ m$, $\delta = +78°$. *Il ne semble pas y avoir de variations du fond galactique émettant des rayons X mous avec la latitude galactique et ce résultat est discuté.*

Summary. — *Final results are presented for a March 20, 1963 search for night sky sources of soft X-rays. Although one sky region was found to be associated with an X-ray flux 2,5 to 3 standard deviations above background, the probability of observing one random fluctuation of this importance in the data for the night sky is estimated to be as high as 20 %. The region is located at* $\alpha = 23\ h\ 40\ m$, $\delta = +78°$. *Apparently negative results from a search of the data for variations of X-ray background with galactic latitude are presented and discussed.*

Резюме. — Даны окончательные результаты расследования источников мягких лучей X в ночном небе (20 марта 1963). Только один участок неба дал сигнал превышающий в 2,5-3 раза наиболее вероятное статистическое отклонение, тогда как вероятность наблюдать случайное статистическое отклонение этого порядка равна 0,2. Участок определен координатами α 23 = 40 м $\delta = +78°$. Как будто нет изменений галактического фона, излучающего мягкие лучи X, с галактической широтой и этот результат обсужден.

1. Introduction.

On March 20, 1963, a rocket experiment was performed in an attempt to locate and obtain spectral information about stellar sources of soft X-rays in the 0.2 — 20 keV (60 — 0.6 A) range. The X-rays were detected by several well collimated (5° × 10°) gas filled proportional counters protected by anticoincidence plastic-scintillator-photomultiplier shields. Preliminary results of this Aerobee 4.70 rocket flight and an earlier similar experiment on Aerobee 4.69 have already been presented [3]. Final results for the Aerobee 4.70 flight are given here.

2. Isophote plot construction.

Figure 1 is a celestial sphere isophote plot derived from all counts recorded by the Aerobee 4.70 detectors and is based on a more accurate and extended vehicle aspect solution than was used for the preliminary results [3]. The extended solution permitted inclusion of data from two more scans (to a total of 11 scans) of the sky. Model atmosphere calculations have shown the flux of night sky X-rays from the two additional scans are essentially free of absorption effects. The rocket's 0.5 — 3.5 keV and 2 — 20 keV counters alternately observed the upward (night) sky and the downward (earth-obscured) sky. Each detected event was assigned to an elemental area of the celestial sphere. The rocket's motion was such that individual elemental areas were scanned from 2 to 9 times by each of the detectors. Observed events were also segregated into two broad and overlapping energy intervals, 0.5 — 8 ke.V and 4 — 20 keV. Preliminary results from this revised data analysis procedure were presented at The Meeting on Neutron Stars and Celestial X-Ray Sources held in New York on March 20, 1964. A noticeably high count rate in a given sphere region was compared to the background count rate predicted for that particular region in order to assess the statistical significance (number of standard deviations σ above background) of the high count rate. Although σ values for the night and earth-obscured sky were based on slightly different (and independently calculated) back-

(*) Communication présentée au Symposium n° 23 sur les Observations astronomiques faites à bord de véhicules spatiaux, tenu à Liège (Belgique) du 17 au 20 août 1964.

ground rates, for each sky region all detected events were assumed to occur randomly in time. Because both the night and earth-obscured sky were arbitrarily terminated 15° from the horizontal horizon, the night sky background was used for the horizon region.

An allowance for the variation of detector efficiency with angle off the counter's centerline was made as described in [3]. After the isophote plot was finished, the σ value for each high count region was recomputed using the total of all possible counts (no allowance for angular distribution) which might be associated with the high count location. While the differently computed σ values of a given high count region never differed by more than $0.5\ \sigma$, all Figure 1 regions are shown with the lowest σ values computed.

3. Results.

With the exception of what appear to be horizon related sources, only a single region is as much as $2.5\ \sigma$ above the predicted background. The count rate was noticeably high on five or the seven successive passes over this region and the actual counts in the 0.5 — 8 keV interval total 25 as compared to a predicted background of 14. Unfortunately, the relatively stronger Scorpius source [1, 5, 6, 7] was below the rocket horizon on both the Aerobee 4.69 and 4.70 flights and so could not have been observed. Our failure to detect the Grab Nebula source observed by the Naval Research Laboratory group has been particularly noted by Bowyer [2] and several of his remarks have been discussed in a Letter by Fisher and Meyerott [4]. Figure 1 contains data from 3 scans directly over M1, as compared to the single direct scan (out of a total of 3 scans) utilized in [3]. However, the total 0.5 — 8 keV interval count for the Crab Nebula location of 9 (compared to a background of 11) is still statistically less significant than the count for several other regions scanned. Either our : *a*) low detection sensitivity ($\sim 1/5$ that on the NRL flight) or *b*) fairly broad energy intervals (which effectively suppress sensitivity), may be the cause of our not detecting the Crab Nebula source.

Several investigations of the correlation between high count regions and approximate celestial sphere position have been made in addition

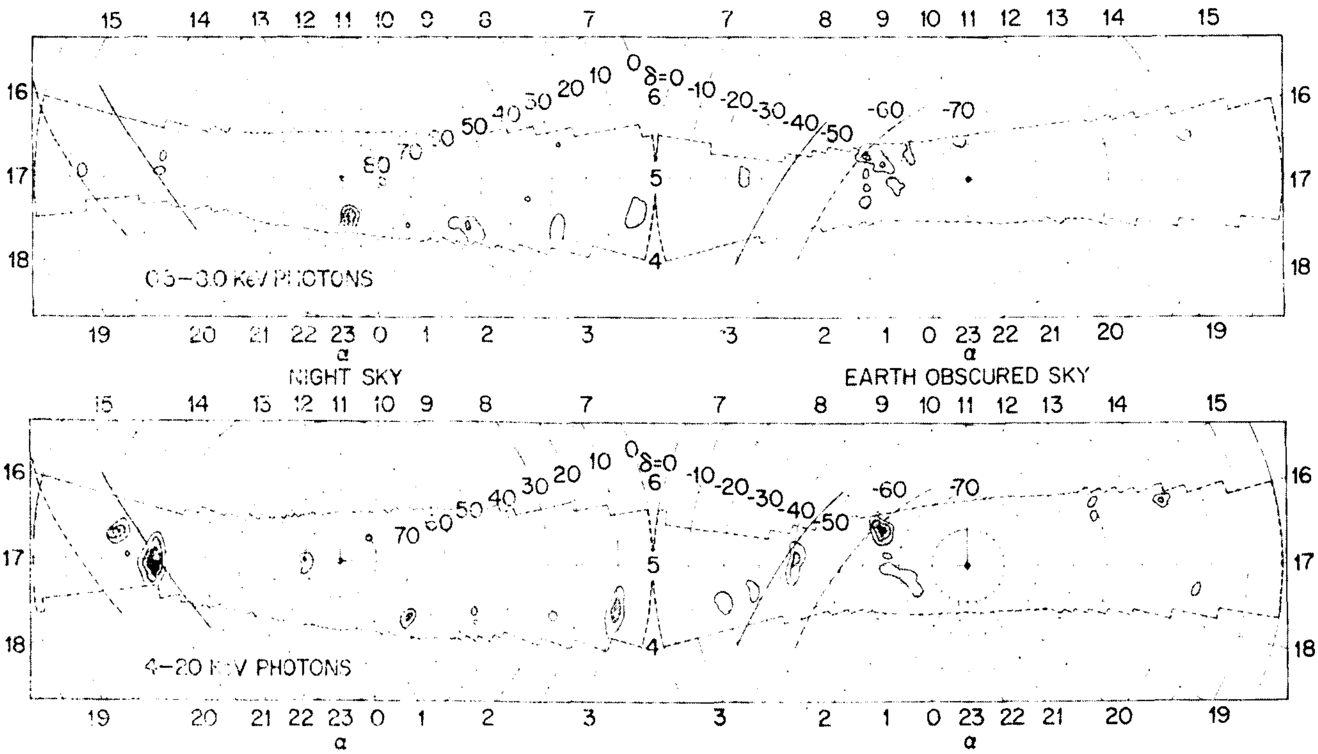

Fig. 1. — Celestial sphere isophote plots of high count regions observed by Aerobee 4.70 detectors. The solid and dashed lines separating the night sky from the earth obscured sky represent the horizontal and rocket horizons respectively. The simply outlined, cross-hatched, and blackened areas indicate count rates $1.5\ \sigma$, $2.0\ \sigma$ and $2.5\ \sigma$ above background.

to the search for point source locations discussed above. Figure 2 contains the results of a correlation attempt in which the area of Figure 1 high count regions (in terms of square degrees) was plotted along the line down the center of the combined scans given in Figure 1. The only finding of apparent significance is the previously mentioned clumping of high count regions near the earth's horizons.

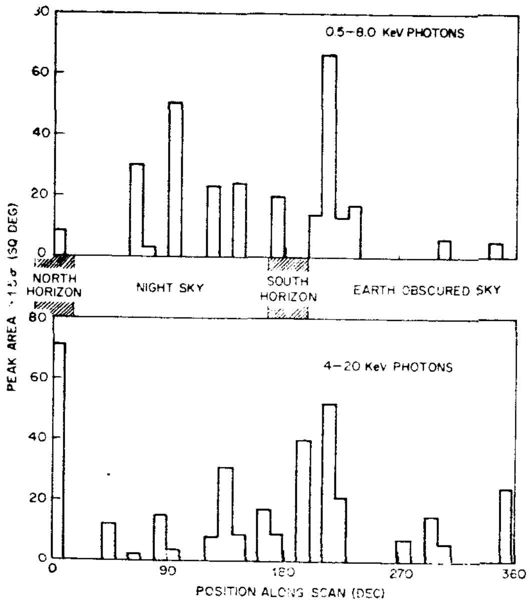

FIG. 2. — Test of Fig. 1 results for clumping of high count regions along the line of scan.

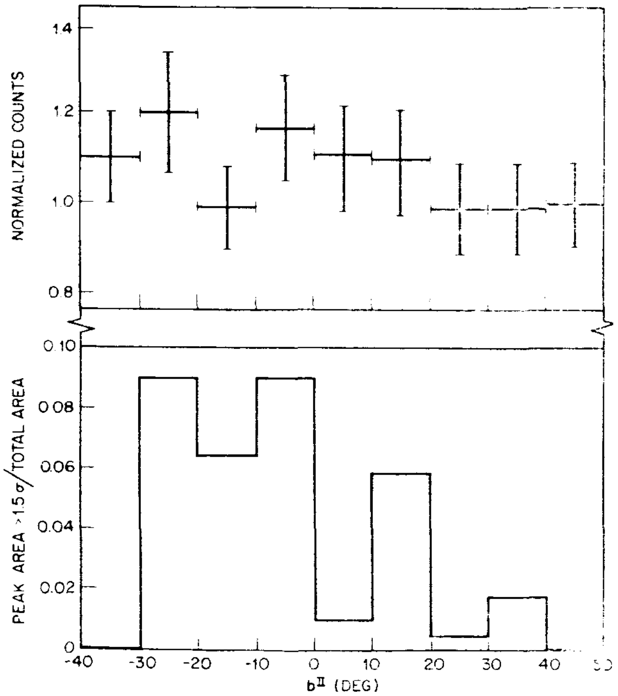

FIG. 3. — Plots of 0.5-8.0 keV X-ray data for evaluating galactic latitude dependence. The top portion of the figure presents all counts observed, while the bottom portion of the figure represents only the counts $1.5\,\sigma$ above background.

Figure 3 gives the results of two other correlations attempted, both of these particular correlations being based on data for the 0.5-8 keV energy range. Normalization for the top portion of Figure 3 was derived by comparison with the average value of $1.88 \pm .07$ counts/cm^2-s obtained from a similar plot for the earth-obscured sky. The apparent 6 % excess of 0.5-8 keV night sky (over earth-obscured sky) photons actually amounts to $.11 \pm .07$ counts/cm^2-s and is almost completely due to 2-8 keV photons. After allowing for the 1/50 Sr effective solid angle of the collimator and the 0.7 value of counter efficiency, the excess counting rate is found to be equivalent to 8 ± 5 photons/cm^2-s-sr. Previous measurements of this quantity [1, 7], yielded a value of 6 photons/cm^2-s-sr. Similar treatment of the 4-20 keV data shows more counts per second from the earth-obscured sky than from the night sky. Consequently the X-ray flux from the night sky is indeed somewhat softer than that observed when looking down at the earth's atmosphere.

Results of a third correlation attempt are given in the bottom portion of Figure 3. The area of Figure 1 high count regions (in terms of square degrees, using σ values derived from the angularly distributed counts) was examined for a galactic latitude dependence. A trivial correction was made to allow for the fact that the rocket's precession resulted in slightly different degrees of overlap of the many successive scans over each latitude interval. Although a latitude variation does appear, the actual X-ray fluxes are so small as to render the variation of questionable statistical significance. Except for one peak in the $-20°$ to $-30°$ latitude interval, a similar investigation of the counts associated with 4-20 keV pulses shows no latitude variation.

4. CONCLUSIONS.

Complete re-analysis of the Aerobee 4.70 flight, utilizing all data available, has led to approximately the same quantity and location of high count regions given previously [3]. However, because of their low statistical significance, the Aerobee 4.70 data alone are insufficient to establish the real existence of any of the high count regions. The two possible exceptions to this finding are the aggregate of regions in the vicinity of the earth's horizon and the region at $\alpha = 23^h\ 40^m$, $\sigma = +\ 78^o$. A night sky flux of 8 ± 5 photons/cm^2-s-sr found for the 4-8 keV range agrees well with values obtained by other observers. The 8-20 keV X-ray flux from the earth's atmosphere is noticeably larger than that from the night sky. A variation (of uncertain statistical significance) with galactic latitude was found for the 0.5-8 keV X-rays coming from a swath of sky which cuts diagonally across the galactic equator near 160^o of longitude. This work was supported by the National Aeronautics and Space Administration under contract NAS 5-1174 and by the Lockheed Independent Research Program.

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APPENDICES

(Articles to be published in 1966 will appear in)

D. Proceedings of the Second Texas Symposium on Relativistic Astrophysics

E. The Astrophysical Journal, 143

NIGHT SKY X-RAY SOURCES

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NIGHT SKY X-RAY SOURCES

ABSTRACT

A survey for x-ray sources at low galactic latitude and in the longitude range $340^{\circ} < \ell^{II} < 160^{\circ}$ has been made. At least eight different sources were detected. Six of these were found to have a longitude within 20° of the galactic center although none of these sources appear to be at the galactic center itself. Spectral information, in the energy range of about 2 to 20 keV, was obtained for the bright Scorpius source. The low flux of photons less energetic than 4 keV prevents a good fit of the Scorpius spectral data to either Planck or power law energy distributions.

NIGHT SKY X-RAY SOURCES

On 1 October 1964, a survey of night sky x-ray sources lying at low galactic latitudes was performed from a rocket launched at White Sands, New Mexico. As data reduction is not complete, this contribution is in the nature of a progress report and is primarily concerned with a description of the experiment and a preliminary appraisal of the results obtained. Some spectral information for the x-ray source in Scorpius will be given and the location of a number of sources in the general direction of the galactic center will be noted.

At the time the observing program was selected, only two x-ray sources appeared to have been reliably located. The positions were for: 1) the bright source in Scorpius observed by Giacconi et al. (1962 and 1963), and Bowyer et al. (1964), and a source presumed by the latter to be the Crab Nebula. Several other source positions had been tentatively identified. These included a) a source in the range of galactic longitudes encompassing Cygnus and noted by Giacconi et al. (1962 and 1963), b) a source in Cepheus suggested by data from the two rocket flights of Fisher and Meyerott (1964), and c) a source in the vicinity of Cygnus suggested by (unpublished) data from one rocket flight of Fisher and Meyerott.

An attitude control system (ACS) caused the rocket to maneuver so that x-ray and optical star sensors scanned slowly near the galactic equator in the manner shown in Figure 1. The detectors had three differently oriented rectangular-shaped fields of view as indicated near the left of the figure. The scan rate was nearly constant during each scan and these rates are given in the figure. In addition to the scan along the galactic equator, Figure 1 indicates that three observations of the Scorpius and one additional observation of the Cygnus regions were planned. Because of a malfunction in a rocket component, the flight was terminated several seconds prior to the planned second scan of Cygnus. Difficulties with the flight's x-ray detectors resulted in only one counter providing data during scan 1.

The x-rays were detected by sealed gas proportional counters having either beryllium or aluminum windows. The detector sensitivity was highest at about 6 keV and fell off rapidly at higher and lower energies, the low energy cutoff being about one keV. Pulses from the detectors were amplified, analyzed for amplitude and sorted into several energy channels by the rocket instrumentation.

By reduction of data from the various x-ray detectors and optical star sensors, positions of x-ray sources relative to the observed stars can be obtained. In order to locate a source accurately in two celestial coordinates, it must be observed by more than one counter-collimator system. Because only one counter-collimator system provided good data during scan 1, only one angular coordinate can be determined accurately for the sources observed on this scan. Thus the position along the scan is well determined while the position perpendicular to the scan is limited by the 26° full width at half maximum of the field of view.

The counting rate in the energy channel spanning the nominal range of 4-8 keV was observed to increase from its background value of about 75 counts/sec to rates in the range of 200 to 400 counts/sec several times during the first scan. The first occasion was when Cygnus was being traversed. For this source the counting rate versus time profile exhibited a well defined triangular shape compatible with a single source having an angular extent small compared to the collimator resolution. At the same time, the counting rate in the 8-12 keV channel rose a detectable amount above its background level. The other regions of enhanced counting rates were grouped in longitude within about $\pm 20^{\circ}$ of the galactic center and were not completely resolved from each other. However, the count rate profile for 4-8 keV photons shows six distinct peaks, each of which could have the proper triangular shape. Four of these peaks lay on one side of the galactic center, and two on the other side. One of the strongest sources observed was about one degree from the galactic center. While the latter position is apparently not associated with the strong peak nearby, the peak's presence makes it difficult to say whether there is any radiation from the galactic center itself.

As noted above, for the Cygnus source only the angular distance along the scan path can be obtained accurately from the October 1 flight data. The longitude of the source is in the range of $70^{\circ} < \ell^{II} < 74^{\circ}$. Previously unpublished data of Fisher and Meyerott may be of use in further specifying the source's location. The highest counting rate observed on either of their two earlier flights (excluding the rates obtained when observing near the earth's horizon) was associated with the region $60^{\circ} < \ell^{II} < 100^{\circ}$ and $-5^{\circ} < b^{II} < 12^{\circ}$ which was scanned on one flight only. The narrow dimension of the line-shaped fields of view of the first flight's detectors were nearly orthogonal to those of Aerobee 4.120 for scans of the Cygnus region. Therefore the latitude of the source may be specified as $-5^{\circ} < b^{II} < 12^{\circ}$, assuming the earlier data were indeed related to this source. This approximate position agrees quite well with the NRL location of Cyg XR-1 (Bowyer et al., 1964). The Cepheus source has been proven to be spurious.

The bright source in Scorpius was observed through each of three counter-collimator systems on each of the last three scans, and was found to be within one degree of the position given by Bowyer et al. (1964). Ultimately, a position of this source will probably be established to an accuracy better than 30 minutes of arc from these data.

Little can be said about the spectral distribution of the sources observed on scan 1. However, the spectral data on the bright Scorpius source is believed to be good. The peak counting rates observed (above background) during the scan 3 transit in the 2-4 keV, 4-8 keV, 8-12 keV and 12-20 keV channels were < 30, 3000, 400, and ~ 100 counts/sec respectively. The results of one of the first attempts at understanding the Scorpius spectrum are shown in Figure 2. The counts observed in each of the various energy intervals were divided by the product of detection efficiency and energy width and the resultant set of numbers arbitrarily normalized to unity in the 8-12 keV interval. This procedure gives equal weight to the detector efficiency at each photon energy. For comparison purposes, two Planck distributions characterized by kT values of 1.5 and 2.0 keV have been included in the figure, k being the Boltzmann constant. A temperature of the order of 16×10^6 °K, corresponding to a kT of 1.5 keV, crudely describes the three higher energy data points. Preliminary attempts to fit the three higher-energy data points to a power law indicate the photon flux falls off as E^{-2} or E^{-3}, where E is the photon energy. The upper limit obtained from the lack of data in a fourth energy interval ($E < 4$ keV) of the same detector indicates a shortage of low energy photons. A question mark has been placed beside the upper limit in the figure to indicate concern over the significance of the limit. Although an allowance for all the various experimental errors has not yet been made, the apparent shortage of low energy photons is sufficient to render both the Planck and power law distributions inadequate as descriptions of the Scorpius energy spectrum.

Failure to fit the data to a spectrum controlled by a single parameter has led to attempts to fit the data to spectra controlled by two parameters. The three higher-energy data points could be fitted to a bremsstrahlung distribution provided the maximum electron energy were of the order of 20 keV and there were more low energy than high energy electrons. Successful two-parameter fits have also been made to distributions consisting of either an emission line or an absorption edge near the center of the 4-8 keV range superimposed on a Planck distribution having a temperature of the order of 40×10^6 °K. Because satisfactory agreement could undoubtedly be found for many other combinations, one must conclude that the data are inadequate to accurately specify the spectral distribution of the source.

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FIGURE CAPTIONS

1. The shaded areas in this galactic coordinate plot show the various swaths of sky scanned for x-ray emission. To the left, at the beginning of scan 1, the three different fields of view are schematically shown. Except for the incomplete last scan, the center of each detector's field of view moved along the indicated scan lines as the rocket rotated slowly about an axis nearly perpendicular to the galactic equator.

2. Four-point spectrum obtained for the bright Scorpius source. Lack of sensitivity in the lowest energy interval has resulted in only an upper limit to that interval's flux. The error bars give only statistical errors in counts and so do not include errors in the detector's response function.

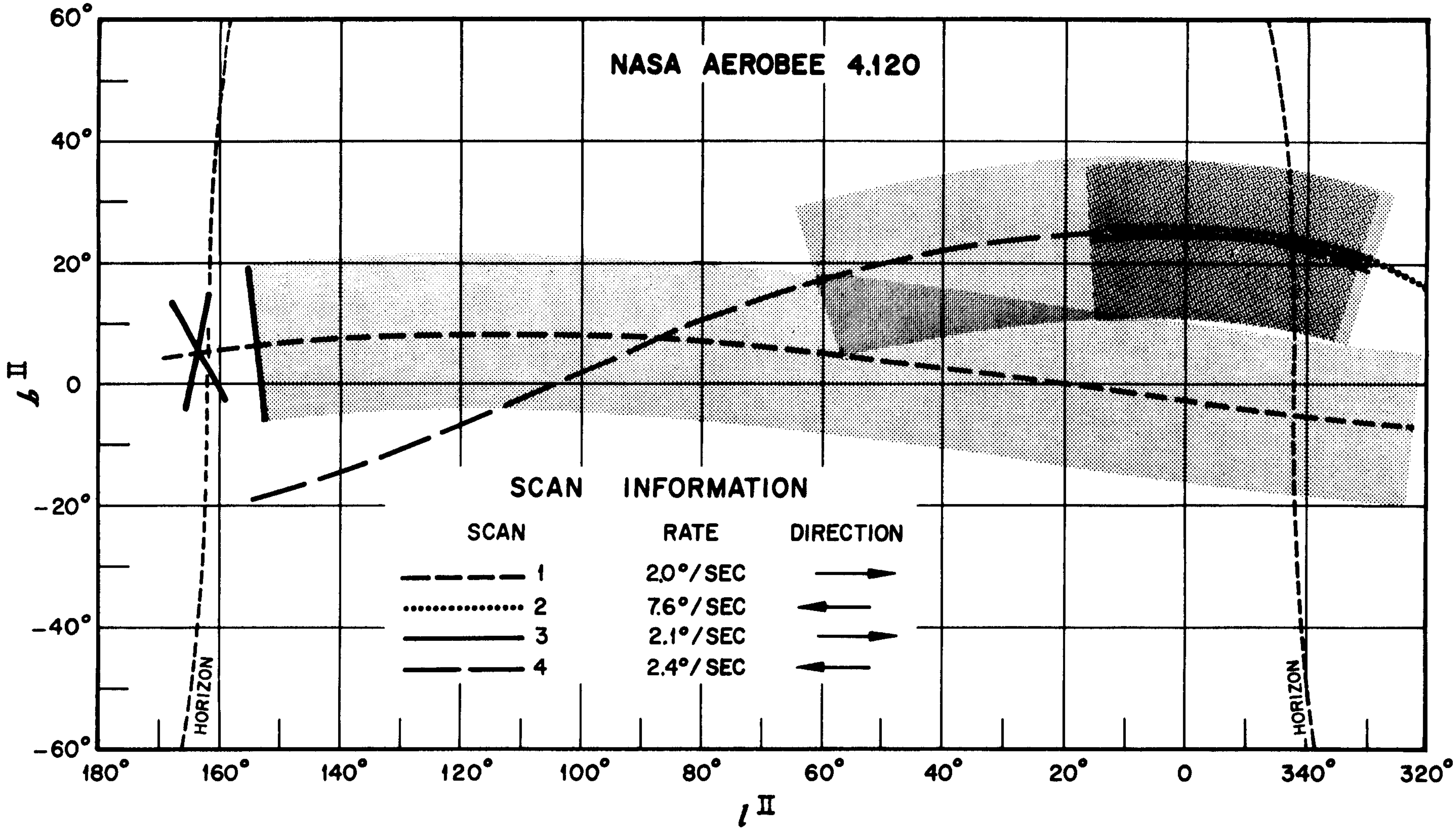
NASA AEROBEE 4.120
SCAN INFORMATION
SCAN
RATE
DIRECTION
1
2.0°/SEC
2
7.6°/SEC
3
2.1°/SEC
4
2.4°/SEC
HORIZON
HORIZON
60°
40°
20°
0
-20°
-40°
-60°
180°
160°
140°
120°
100°
80°
60°
40°
20°
0
340°
320°
b^{II}
l^{II}

Figure 1

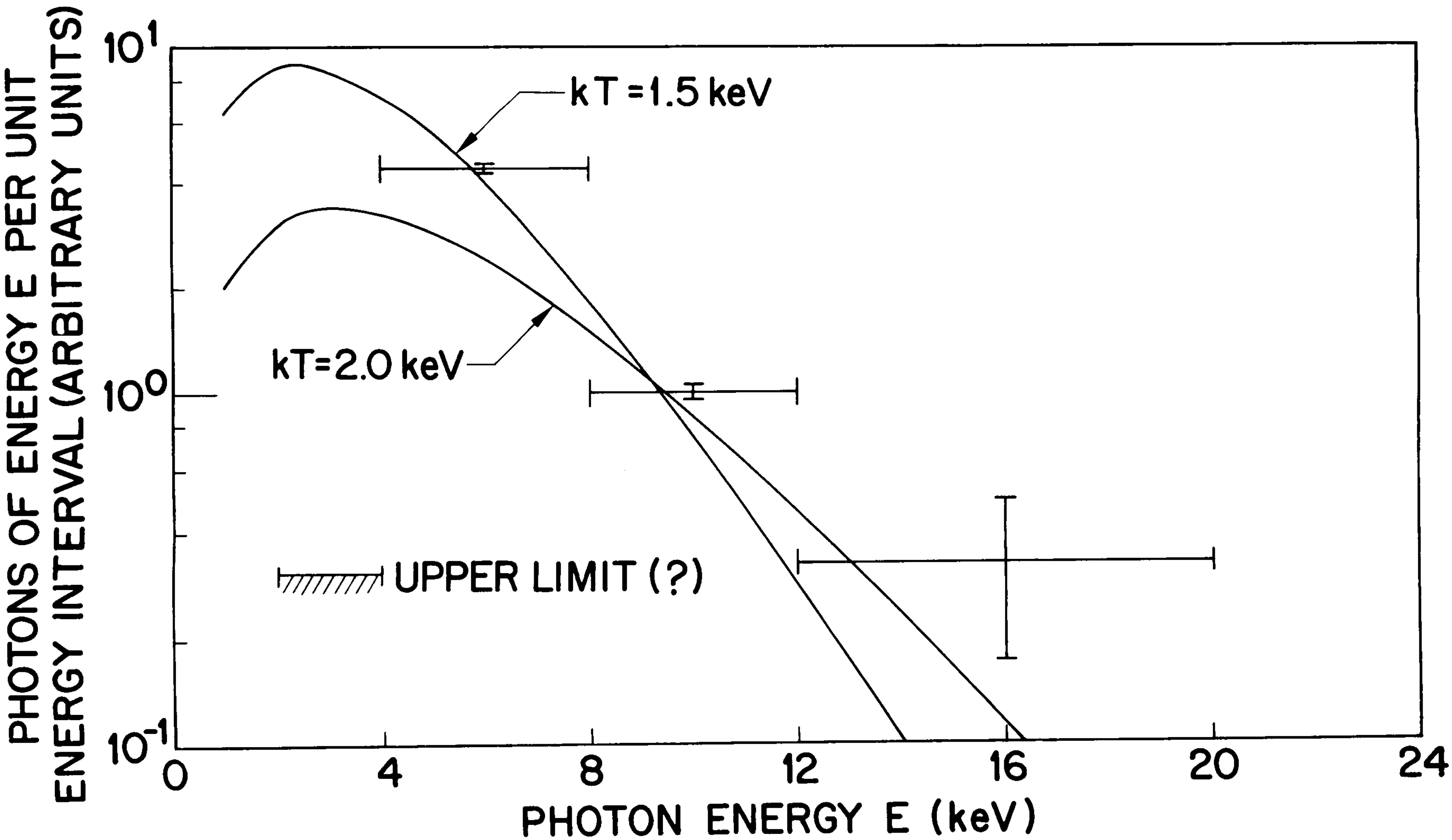
PHOTONS OF ENERGY E PER UNIT
ENERGY INTERVAL (ARBITRARY UNITS)
10^1
10^0
10^-1
0
4
8
12
16
20
24
PHOTON ENERGY E (keV)
kT = 1.5 keV
kT=2.0 keV
UPPER LIMIT (?)

Figure 2

OBSERVATIONS OF COSMIC X-RAYS*

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May 7, 1965

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ABSTRACT

Results are presented for eight X-ray sources observed on a 1 October 1964 rocket flight. The most detailed information is for the brightest source in Scorpius which has been located at $\alpha = 16^h\ 14^m \pm 1^m$, $\delta = -15^\circ\ 36' \pm 15'$. Although seven of the eight sources lie inside the longitude interval $344^\circ < \ell^{II} < 16^\circ$, no measurable quantity of 4-8-keV X-rays is associated with the positions of Kepler's supernova or the galactic center. The spectrum of the brightest Scorpius source is peaked in the 4-8-keV range. For all sources, more flux is observed in the 4-8-keV interval than in the 8-12-keV interval. The results are compared with measurements of others.

I. INTRODUCTION

A rocket survey of X-ray sources lying at low galactic latitudes was performed on 1 October 1964. The experiment was designed to search near the galactic equator for new sources of X-ray emission, and to obtain spectral and positional information for the brighter sources observed. In addition, further examination of the bright source in Scorpius (Giacconi et al. 1962, 1963, Bowyer et al. 1964a) was planned. The rocket was equipped with an attitude control system (ACS) which permitted examination of pre-selected portions of the celestial sphere.

At the time the ACS program was set up, only two positions for sources were reliably known. The first of these was the Scorpius source discovered by Giacconi et al. (1962) and more accurately located by Bowyer et al. (1964a). The latter group also observed a source in Taurus which they presumed to be associated with the Crab Nebula. In a subsequent experiment Bowyer et al. (1964b) utilized the lunar occultation of this X-ray source to obtain its precise position and a measure of its angular extent.

The description of the experiment and the results obtained have been divided into six parts. Part II of this article covers the observing program and the instrumentation. Part III discusses the method of determining source position and presents results for eight X-ray sources that were observed. Except for the brightest Scorpius source, the position of each source can only be specified as lying on a segment of a great circle on the celestial sphere. Part IV is concerned with the X-ray spectral information obtained and the apparent brightness of each of the sources. The cosmic X-ray background is evaluated in Part V. The positional and spectral information given and evaluated in Parts III and IV respectively are summarized briefly in Part VI.

II. INSTRUMENTATION

A. Attitude Control System and Observing Program

The rocket instrumentation was based upon use of the NASA-developed attitude control system (ACS) and consisted of five gas-filled proportional counters and collimators, and three photometers for detecting visible starlight to determine X-ray detector aspect. In essence, gas jets of the ACS caused the rocket's longitudinal or roll axis to point nearly at the galactic poles, then the rocket was rotated about this fixed roll axis. The X-ray detectors and starlight-sensing photometers were mounted to view the sky in a direction nearly normal to the roll axis. The observing program is illustrated in Figure 1, which shows the zones on the celestial sphere that were viewed by the detectors. The first scan was a sweep along the Milky Way from northern to southern horizons. Between scans 1 and 2, the roll axis was shifted to the new orientation required for scans 2, 3, and 4. All of the lines indicating paths of collimator centerlines in Figure 1 have been plotted on the basis of the reduced optical star-sensor data, except for the latter part of scan 4, which was to have terminated at the northern horizon. The ending of the scan 4 shaded area near 60° of longitude signifies the end of the useful data-taking portion of the flight. Each scan was controlled by momentary ejections of gas through jets associated with one of the rocket's three (roll, pitch, and yaw) axes.

The ACS program shown in Figure 1 called for scanning: (1) along the galactic equator in such a manner as to traverse the galactic center; and (2) across the position of the brightest Scorpius source. The observing program was arranged, in part, to have the Scorpius source far enough above the horizon that there would be little atmospheric attenuation of low energy ($\sim$1 keV) X-rays from the source. Examination of the region near the galactic equator was to be carried out in such a manner that two scans would be made in the vicinity of Cygnus. This region was of special interest because it had been listed as a possible source position by Giacconi et al. (1962) and was also suggested by data from one of the two rocket flights of Fisher and Meyerott (Fisher, Jordan, and Meyerott, 1966).

To obtain position information for the sources observed, and at the same time provide some redundancy, detectors with three separate fields of view were employed. The rectangles outlined at the beginning of scan 1 in Figure 1 indicate the portion of each detector field of view which could be viewed with a collimator transmission greater than 50 per cent. The detector designations T, C, and B refer to their relative position in the rocket's instrumentation compartment, being top, center, and bottom respectively. The shaded area indicates the swath of sky scanned by detector C. Figure 2 is a portion of the telemetry record of scan 3. The brightest scorpius source was observed at about 265 sec after launch by detector C and then nearly simultaneously at about 269 sec by detectors T and B.

Each counter's field of view was restricted by a cellular aluminum collimator. While each individual collimator cell had an aperture of 0.15 in. x 1.5 in., use of cells of different lengths resulted in the two different-sized fields of view shown in Figure 1. For the collimator of detector C, the field of view for full width at 50 per cent transmission corresponded to acceptance angles no larger than $2\overset{\circ}{.}9 \times 26\overset{\circ}{.}5$ for low-energy photons.

Counter C's field of view was pointed about 9° away from the intersection of the fields of the other X-ray detectors and the aspect sensors. The long dimensions of the fields of view of the T and B counters were skewed 40° with respect to each other (plus and minus 20° with respect to counter C's field of view). In the scanning direction, the collimation was markedly narrower than that used by the other groups investigating cosmic X-ray sources. To cover a large area of the sky, a broad collimation was used normal to the scanning direction.

B. X-Ray Detectors

Each gas-filled proportional counter was an array of individual counters. Three of these arrays had large-aperture (263 cm^2 effective, 5-mil thick) beryllium windows. The other two arrays had small-aperture ($\sim$ 18 cm^2 effective, 0.5-mil thick) aluminum windows. All gas counter elements were 4.0 cm deep, and were filled to a pressure of 83 cm of Hg with a 90 per cent argon and 10 per cent methane gas mixture. The resultant efficiency of these counters for detecting various energy photons is shown in Figure 3a. Three of the five counters gave useful data. These were the beryllium-window counters T and C, and the aluminum-window counter B. Only counter C was not equipped with a plastic scintillator anticoincidence shield for reduction of cosmic ray background effects.

For each photon detected, a gas proportional counter produces an electrical pulse whose amplitude provides a measure of the energy of the event. All pulses obtained from the beryllium-window counters were analyzed for amplitude aboard the rocket and then assigned to one of four photon energy intervals. The analysis was performed by a differential pulse-height analyzer made up from five stacked discriminators. Information about the number of counts in each energy interval was telemetered to the ground after being treated by one of two procedures. The Figure 2 data for counters T and C indicate one procedure. Counts were scaled in such a manner that each horizontal bar in the telemetry record represents the occurrence of four counts in the given spectral interval. Each eight-step sequence, therefore, indicates 32 counts. The second procedure for treating counts was used for the data in other energy intervals of counters T and C and is indicated by the counter B data of Figure 2. The counting rate of pulses allocated to a given energy interval was read continuously and the rate then converted to a voltage which was telemetered to the ground. The peak rate of the linear scale on the detector B trace corresponds to 600 counts per sec. For some energy intervals, sampling was performed for only 0.03 sec once every 0.14 sec.

A detailed description of the response of detector C is given here because this detector provided the majority of the flight's spectral information. Each chamber of this counter had the detection efficiency shown in Figure 3a, where the estimated accuracy is ± 5 per cent. Figure 3b shows the calculated probabilities that counter C and its associated circuitry would detect and assign the pulse of a photon of stated energy to one or another of the energy intervals. These intervals are nominally defined as 2-4-keV, 4-8-keV, 8-12-keV, and 12-20-keV and were established by the pulse-height analyzer settings. The four individual chambers produced voltages in response to a single photon energy which were in the ratios of $1/(1.00 \pm 0.05)/(0.80 \pm 0.08)/(1.15 \pm 0.05)$. These relative gains were measured with 5.9 keV X-rays from an Fe^{55} source which was used to monitor each chamber's gain before and after the counter's flight. The different gas gains of the various chambers were partly responsible for the overlap of the energy intervals shown in Figure 3b.

Part of the uncertainty in energy resolution is associated with the detection process itself and is inherent in the Gaussian distribution of pulse heights which would be produced by detection of a large number of monochromatic photons. Full width at half maximum of this Gaussian distribution is ~ 18 per cent of the mean pulse height from 5.9 keV X-rays. Because photons of a given energy may indeed produce signals of more than one pulse height, an uncertainty in the quantity of photons per unit energy interval arises which is comparable with the uncertainty introduced by the different chamber gains.

Detection of photons more energetic than 3.2 keV is sometimes accompanied by emission of a characteristic argon X-ray. If this X-ray leaves the counter before being absorbed, the pulse amplitude associated with the detected event is smaller by the amount of the escaped argon X-ray. The 5-7-keV efficiency of the first energy interval arises from this escape-peak effect. All of the effects discussed above have been included in Figure 3b.

C. Aspect Sensors

Three starlight sensors provided signals for determining the aspect of the X-ray counter-collimator systems. All three sensors utilized 2-in, f/2.3, achromatic object glasses. The focal planes of two of the sensors were scanned by holes in rotating disks. These holes admitted sky background light and starlight to end-on photomultipliers. Because the holes admitted light from one square degree of the sky, these two aspect sensors did not locate stars as accurately as the third unit. Consequently, information from this pair of star sensors has served chiefly to confirm the results obtained from the third sensor.

In the latter unit, the optics and electronics were the same but the fixed focal-plane diaphragm contained a narrow V-shaped slot. For this reason the sensor has been designated the V-sensor (photometer V in Figure 2). The axis of symmetry of the V was parallel to the roll axis of the rocket and to the long dimension of detector C's field of view. The direction of view of the V-sensor approximately coincides with the intersection of the fields of view defined by collimators T and B. As the rocket rolled, each side of the V slot transmitted the light of a star image, within a few seconds of time. The mean time of the two signals from a star gave the rocket's position in roll angle and so fixed the roll orientation of collimator C. The difference in the signal times of a single star provided a measure of the angle from the roll axis to the star during the roll maneuver. The difference in mean times for two stars gave the average roll rate between them.

III. SOURCE POSITIONS

A. Aspect Solution and X-Ray Data

The specification of source positions will be presented by considering the sources observed by a single counter-collimator system separately from the brightest Scorpius source which was observed by more than one system. Coordinates for the epoch 1950 will be used throughout this paper for specifying position.

The problem in specifying source positions is to determine precisely the orientation of each X-ray collimator in celestial coordinates as a function of time throughout the rocket flight. The time of observation of a source through a given collimator establishes, within observational errors, a great circle segment upon which the source must lie. When more than one observation of a given source is available, the intersection of the great circles specifies the source's position. As noted above, the orientation of the collimators at a given instant is determined primarily by reduction of data from the starlight sensor with the V-shaped diaphragm.

The transit times of 1st or 2nd magnitude stars and sometimes of fainter stars could be read on the recorded graph to within about 0.02 sec. At a constant roll rate of 2^{o}/sec, this uncertainty in timing corresponds to a 3' uncertainty of position in the direction of scan. However, possible variations of the roll rate, and especially errors in measurement of the relative positions of the V-sensor and the X-ray collimators, introduced larger uncertainties in the determination of the position of each X-ray source.

The detector response to a point source, in terms of counts per unit time, is an isosceles triangle on top of the background level. A collimator is defined to transit a source at a time t_o when half of the total source-signal counts have been accumulated. These times are uncertain by at least as much as the interval $t-t_o$ required to accumulate the square root of the total number of source counts. This uncertainty is as small as $\pm$ 0.01 sec for the 4-8 keV photons of detector C for the slow scans of the brightest Scorpius source. For six sources that were observed between 204 seconds and 222 seconds, the transit times can only be established to an uncertainty of about $\pm$ 0.1 sec. As expected, there is no difference between the transit times defined by different energy channels of counter C.

Figure 4a is the complete record of the count of 4-8 keV pulses per second observed by detector C during the flight. The atmospheric transmission T was predicted on the basis of a model atmosphere of

Anderson and Francis (1964) calculated for the flight conditions, and the use of tables by Wilkes (1954) and Swider (1964). Figures 4b and 4c provide greater resolution of the detector-C data during scan 1 along the galactic equator. For reasons still unknown, useful data on scan 1 came primarily from detector C.

B. The Brightest Source in Scorpius

The principal data for this source were obtained from counters B, C, and T during scans 3 and 4. Scan 2 was so fast that only the large aperture counters, C and T, produced usable data. Three determinations of the source position can be obtained from the transit-time data in each of scans 3 and 4, while only one position can be determined from scan 2. These positions are all given in Table 1. Each entry in the table depends on six times: t_1 (ζ Oph), t_2 (ζ Oph), t_3 (δ Sco), t_4 (δ Sco), t_5, and t_6. The first four times are for transit of the two reference stars in the V-sensor, and t_5 and t_6 are representative transit times of the Scorpius source in any pair of X-ray collimators. The transit times of the reference stars closely bracket the transit times of the X-ray source. The lack of measurable roll-rate variations allowed the rocket's motion to be treated as a roll at constant rate on a fixed axis throughout the observing time interval for scans 3 and 4. For scan 2, the variation of the roll rate was large but measurable on the ACS roll rate data, so that angular distances were integrated from the variable rate over the various time intervals. Having determined the V-sensor orientation at $(t_1 + t_2)/2$ and $(t_3 + t_4)/2$, the location of the

X-ray detector fields of view follows from t_5 and t_6 and the measured angles between the V-sensor axis and the X-ray collimators.

Errors in transit times t_5 and t_6 and errors in measurments of the angular orientations of the collimators with respect to each other cause the spread in the values of Table 1. The latter errors enter into each scan in the same way, i.e. systematically. The values in Table 1 are not completely independent, since the collimators act conjointly. Another source of error in the position of the Scorpius source arises from the error in the angles from the V-sensor to the collimators. The estimate of the probable error in the following mean position of the source takes account of all these factors. The result is $\alpha = 16^h\ 14^m \pm 1^m$, $\delta = -15^\circ\ 36' \pm 15'$.

The maximum angular size of the Scorpius source can be estimated from the 4-8-keV count rate pattern of detector C. The count-rate response of the detector could have been influenced by variations in the rocket roll rate, irregularities in the cell structure of the collimator, and extension of the source. Because the estimate of size involves a model of the source, the latter was assumed to be a disk of uniform surface brightness. The apparent blunting of the top and the rounding of the feet of the measured count rate pattern (cf. Figure 6) indicates the source diameter is $< 1/2^\circ$. Oda et al. (1965) have set an upper limit of $1/8^\circ$ on the size of this source.

C. <u>The Sources Observed During Scan 1</u>

Figure 4 shows that several sources were observed by counter C during the scan along the galactic equator. The sources lie on normals to the scan line at the time of the transit, t_o. Because only detector C provided data, the second position coordinate is not known. Table 2 is a list of the clear-cut sources of Figure 4 and gives positional data in order of t_o. For each source $\cos(\alpha - A) = -\tan D \tan \delta$, is the equation of the great circle upon which the source must lie. A and D are the 1950 right ascension and declination of the poles of these great circles at times t_o.

The Scorpius position derived in the preceding section is inconsistent with the mean of the laboratory measurements of the roll angle between the V-sensor axis and the axis of the C collimator. Although the latter is only one of three collimators that affect the mean, a shift of 5' in the (roll-) angle separating the V-sensor and the C collimator is sufficient to restore consistency. Because this correction is within the probable error of the laboratory measures of the angle, the correction has been used in the reduction of all data of this section.

The Remarks of Table 2 relate the data to some of the "XR" sources observed by Bowyer et al. (1965), and to other objects. The minimum distance σ from the great circle of collimator C (with the pole A, D) at time t_o, to the position of each object at α', δ' is also given in Table 2. This distance is parallel to the direction of scan, and is derived from $\sin \sigma = \sin \delta' \sin D + \cos \delta' \cos D \cos(\alpha' - A)$. The value of σ is positive when α', δ' falls on the north side of the great circle. It must be remembered that the uncertainty in the position of the C collimator in the direction of the scan is about $\pm$ 15'. The error in the position of the great circle upon which the source must lie is considerably less than the quoted error of each "XR" position in the coordinate parallel to the direction of scan. Figure 5 illustrates the relation between the "XR" positions of Bowyer et al. (1965) and the scan 1 sources.

Agreement with the "XB" positions is not satisfactory for Sgr XR-2, which appears to be composed of two nearly equal sources that were resolved during this experiment. Both sources are probably close to the galactic equator. The identification of Kepler's supernova of 1604 with Oph XR-1 (Table 2, No. 4) and the galactic center with Sgr XR-1 (Table 2, No. 5) suggested by Bowyer et al. (1965), has not been confirmed.

Signals which are identified with Sco XR-3 were observed with detector C on scan 2 at t_o = 251.0 sec, scan 3 at t_o = 273.2 sec, and scan 4 at t_o = 287.5 sec, and principally on scan 1. These multiple observations indicate a single non-extended source. Unfortunately, the great-circle projections of the collimator on the sky are so nearly parallel in all of the scans that the position in the direction normal to the scans is only poorly defined. On scans 2, 3, and 4, Sco XR-3 was near the edge of the collimator field of view where only about 2 or 3 per cent of the 4-8-keV photons were transmitted by the collimator.

It was surprising not to find Sco XR-2 in the records of scans 3 and 4, for this source is listed by Bowyer et al. (1965) to be stronger than Sco XR-3, and was closer to scans 3 and 4. This indicates that Sco XR-2 may be at smaller galactic latitude than was found by Bowyer et al. (1965). In short, while the Sco XR-2 and Sco XR-3 signals of the two groups can be properly correlated, there is some difficulty in reconciling source strength and position.

The signal near 195 sec in Figure 4c may be associated with Ser XR-1. By combining these data with a scan 4 signal of comparable strength, a source position within 2^o of that given for Ser XR-1 was determined. Because these two signals are of low statistical significance, and may not be associated with the same object, no entry corresponding to these signals has been included in Table 2. Although Tycho's supernova, Cas A and Cyg A were scanned, no significant x-ray flux above background was associated with these positions.

If the four sources in the range $0^{\circ} < \ell^{II} < 16^{\circ}$ of the 4-8-keV data are "subtracted" as individual point sources from the record of the count rate during scan 1, there may be some signal left above the interpolated level background. The same may be true in the longitude interval containing Sco XR-2 and Sco XR-3. As the details are not clear, no additional source positions have been given in Table 2.

The remaining data concerning source positions are associated with 8-12-keV photons. A significant count occurred 210-214 sec after launch, a period of time nearly twice that required by the counter's field of view to traverse a single source. The counts were too few in number to establish accurately source transit times, or make meaningful correlations with peaks in the lower energy interval.

The contents of this section have been summarized in Table 2, which compares two independent sets of cosmic X-ray source positions. For the majority of the sources, there is satisfactory agreement between the 1 October 1964 survey and the 1964 Naval Research Laboratory survey (Bowyer et al. 1965). However Kepler's supernova and the galactic center are probably not any of the sources. The Sgr XR-2 source of Bowyer et al (1965) has been resolved into two sources. The count-rate profile of all of the sources fits the angular-resolution function of the collimator so that no source is known to be an object of large extent. The most noticeable feature of the distribution of sources observed on October 1 is their concentration toward the direction of the galactic center. Besides Sco XR-1, six certain sources were found in the interval $344^\circ < \ell^{II} < 16^\circ$ and only one certain source in another 150° of galactic longitude.

IV. SOURCE SPECTRA AND FLUXES

A. The Brightest Source in Scorpius

The purpose of this section is to describe the shape of the Sco XR-1 spectrum in the 1-20-keV interval. The data given in Figure 6 indicate the variation of count rate in three nominal energy intervals as detector C swept over Scorpius on scan 3. Only an upper limit was obtained for the count rate in a fourth (lower) energy interval. The results of the three scans over Scorpius are summarized in Table 3. Total counts above background, per scan, rather than peak count rates were used to derive spectral information. While only statistical (standard deviation) errors have been quoted for the 4-8-keV and 8-12-keV counts, errors of the other table entries include estimates of systematic effects arising from conversion of count rates to voltages plus the conversion of intermittently telemetered voltages back into counts/sec.

The difficulty in evaluating parameters which describe the shape of the X-ray spectrum arises from uncertainties in the calibration of the detectors as well as from statistical errors in the observed counts. The spectral parameters quoted below conservatively allow for all the known errors.

The differential photon distribution derived from the detector C counts (Table 3, scan 3) by simply correcting for counter efficiency (Figure 3b) is given in Figure 7. The actual spectral distribution clearly must fall off steeply at both low and high photon energies and is not flat.

To analyze further all the spectral data in the simplest manner, various distributions have been folded in with the counter responses of Figure 3 to predict the ratios of counts in pairs of energy intervals. Comparisons of the predicted and measured ratios of counts for detector C have yielded the majority of the experiment's information on spectral distribution. Single-parameter spectra which have been evaluated for agreement with the flight data include the

Planck distribution

$$\varphi(E) = E^2 \Big/ \left(e^{\frac{E}{kT}} - 1 \right), \text{ and a}$$

power-law distribution

$$\varphi(E) = E^{-(\alpha + 1)} ,$$

where $\varphi(E)$ is the number of photons of energy E per unit energy interval, k is Boltzmann's constant, and T is the temperature of a Planck distribution. α is the index used to describe the spectral distribution of synchrotron radiation produced by a differential energy spectrum of electrons which varies as $E^{-\gamma}$, where $\gamma = 2\alpha + 1$ (cf. Ginzburg and Syrovatskii 1964).

The ratio of counts observed by detector C in any two of the energy intervals can be fitted to a Planck distribution. The counts in the 4-8-keV and 8-12-keV intervals are consistent with a distribution specified by a temperature of $16^{+5}_{-2} \times 10^6$ °K. On the other hand, the 8-12-keV and 12-20-keV data indicate a temperature between 20 and 60 million degrees Kelvin. Despite the apparent overlap of these ranges of temperature, a single temperature of about 20 million degrees is not consistent with the data because a major portion of the quoted errors arises from the response function which produces errors of the same sense when data for different pairs of energy intervals are considered. The upper limit to the flux in the 2-4-keV interval is about one decade less than that expected from a 16×10^6 °K Planck distribution.

The energy calibration for detector T is considered untrustworthy, but reduction of the data shown in Figure 2 does yield a temperature of the order of 16×10^6 °K. Also, folding detector B's efficiency (Figure 3a) into a photon distribution of this temperature predicts counts that are equal to those listed in Table 3, if the different effective apertures of detectors B and C are taken into consideration.

The detector-C data above 4 keV can also be fitted to a power-law spectrum. The 4-8-keV and 8-12-keV data yield $\alpha = 1.8^{+0.3}_{-0.8}$. Because of their imprecision, use of the 12-20-keV data does not further specify α.

The above value of α fails to fit the data for photon energies below 4 keV. The upper limit to the count in the 2-4-keV interval of counter C is a factor of 15 below that required to fit a power-law spectrum having $\alpha = 1$. Also, an index of $\alpha = 1$ would result in a detector-B count nearly twice that actually observed on scan 3. Known errors in the detector-B data are too small to encompass such a discrepancy. Therefore, a power-law spectrum with a single value of the spectral index cannot fit all the data for Sco XR-1.

All three of the higher-energy data points of detector C have also been fitted to a bremsstrahlung distribution produced by thermal electrons. However, the shortage of low energy photons is as inconsistent with this hypothesis as it is with the power law hypothesis.

It is interesting to note that an $\alpha = 1.1$ has been found by Bowyer et al. (1964b) for the few-keV X-rays from the Crab Nebula, and that recent measurements by Clark (1965) of tenfold higher energy X-rays from the Crab Nebula led to an $\alpha = 2$. For Sco XR-1, much hinges on the least reliable data (those for photon energies below 4 keV), which show that the spectrum of Sco XR-1 has a distinct maximum in the 4-8-keV interval. This is completely different from the monotonically increasing flux which may be attributed to the spectrum of the Crab Nebula (Figure 3 of Clark, 1965). Further remarks about the Sco XR-1 spectrum have been made by Fisher, Jordan and Meyerott (1966).

B. Other Sources

Figure 4 presents experimental data for the first scan along the galactic equator and Table 2 summarizes the position information obtained from these data. While the existence of a number of sources is indicated by the 4-8-keV data of Figure 4, a measurable quantity of 8-12-keV photons appeared on only two or three occasions, one of which is correlated in time with the 4-8-keV signal observed from Cyg XR-1. The ratio of the total counts in the 4-8-keV and 8-12-keV intervals indicates that the spectral distributions of the brightest Cygnus and Scorpius sources are comparable in slope. The lack of a measurable flux of 8-12-keV photons for nearly all of the sources observed in the interval $340^\circ < \ell^{II} < 20^\circ$, provides some insight concerning the spectra of these sources. While the 4-8-keV fluxes from the sources near 205, 208, and 218 sec of Figure 4c are all comparable with that observed for the Cygnus source, a significant 8-12-keV flux was not found at any of these times. Consequently, the spectrum of each of these three sources falls off more rapidly with increasing energy than the spectrum of the Cygnus source. A similar argument applied to the remaining peaks (which have still more 4-8-keV counts than the Cygnus source) is inconclusive because of the presence of 8-12-keV photons. No counts above background were observed in the 2-4- or 12-20-keV interval for any of the scan 1 sources.

One other feature of the fluxes measured in this work appears worth noting. All seven of the sources weaker than Sco XR-1 had 4-8-keV photon fluxes which differed by less than a factor of two and were significantly above the background. Although eight objects is a rather small statistical sample, the number of sources of given brightness does not increase as the brightness decreases.

C. Further Comparison of Source Spectra

Additional information concerning source spectra can be derived by a comparison of the actual counts cm^{-2} sec^{-1} from different observations

To do this, the measured peak of each source count rate given in Table 4, column 2, should first be corrected upward to eliminate the effect of reduced collimator transmission with increased angle off-axis. The correction is made by use of the NRL source positions which indicate the angle θ (given in Table 4) from the collimator-C axis to each source at the time of its observation. The ratio of counts cm^{-2} sec^{-1} from the 4-8-keV interval of this experiment to the corresponding quantity from the larger energy interval of the NRL measurements is found to be within the range of 0.6-1.5 for all but the Cyg XR-1 source.

The different flux ratio for Cyg XR-1 may be attributed to a difference in the spectrum. The energy interval examined by Bowyer et al. (1965) encompasses the 4-8-keV interval of detector C and their counter is much more sensitive to low energy photons. Compare Figure 1 of Bowyer et al. (1964b) and Figure 3b above. This difference in detection efficiency indicates the Cyg XR-1 spectrum may contain proportionately more low energy photons than any other mutually observed source. Cyg XR-1 was sufficiently far above the horizon on the various flights that atmospheric absorption effects should have been negligible for photon energies as low as one keV. The relative isolation of the source precludes the measured fluxes being in error because of contributions from neighboring sources.

Because time variations in X-ray flux may some day be observed, it may be worth noting that the fluxes used for Table 4 were derived from three different rocket flights made over only a five-month time interval.

V. COSMIC X-RAY BACKGROUND

Figure 4a shows that at 227-249 sec and 275-285 sec after launch, the average count rate in the 4-8-keV interval of detector C dropped below the average scan background at 137-176 sec, 182-203 sec, and 296-323 sec. During the first two intervals the detector was pointed below the atmospheric horizon. The decrease yields an X-ray component of 0.057 ± 0.005 counts cm^{-2} sec^{-1}, and may represent a cosmic X-ray background (specifically at low galactic latitudes). Upon allowing for the counter's detection efficiency of 0.6 and effective solid angle of 1/32 ster, a background flux of 3.0 ± 0.3 photons cm^{-2} sec^{-1} $ster^{-1}$ is obtained. This is smaller than the 8 ± 5 photons cm^{-2} sec^{-1} $ster^{-1}$ obtained on a previous rocket flight (Fisher et al. 1964). The influence of atmospheric x-rays on these results is not known. For example, similar reduction of the 8-12-keV data yields an increase of $.012 \pm .005$ counts cm^{-2} sec^{-1} when the detector was pointed below the atmospheric horizon.

VI. SUMMARY

1. Eight discrete X-ray sources have been observed. Six of them have been reported previously; the remaining two sources have been listed as a single source by Bowyer et al. (1965).

2. No identifications of X-ray sources with optical or radio sources are made here. In particular, the galactic center, Kepler's and Tycho's supernovae, and Cas A and Cyg A were scanned, but are not identified as X-ray sources.

3. The most striking feature of the distribution of the sources is their concentration toward the direction of the galactic center. Consequently, the observed sources are believed to lie within the galaxy.

4. The instrumental response to all sources is consistent with objects no larger than about one degree in diameter. However, Sco XR-1 is no larger than one-half degree in diameter.

5. The apparent shortage of low-energy photons is sufficient to prevent the Planck distribution, a power-law distribution, or a bremsstrahlung distribution from adequately describing the spectral data of the brightest source in Scorpius.

6. The values of source counts cm^{-2} sec^{-1} observed during this experiment are in fair agreement with those observed by Giacconi et al. (1964) and by Bowyer et al. (1965). The latter comparison shows that more low-energy photons appear to come from Cyg XR-1 than any other mutually observed source.

7. The cosmic X-ray background in the 4-8-keV photon energy interval is estimated to be three photons cm^{-2} sec^{-1} $ster^{-1}$.

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TABLE 1

POSITIONS OF THE BRIGHTEST SOURCE IN SCORPIUS (1950 COORDINATES)

Scan	Detectors	α	δ
2	C-T	$16^h\ 14.4^m$	$-15^\circ\ 48'$
3	C-T	16 15.7	-16 01
3	B-T	16 14.1	-15 24
3	B-C	16 11.4	-15 15
4	C-T	16 15.9	-16 05
4	B-T	16 14.1	-15 25
4	B-C	16 11.0	-15 15

TABLE 2

POSITIONAL DATA OF THE SCAN 1 SOURCES (1950 COORDINATES). A, D LOCATE THE COLLIMATOR'S POLE.

No.	t_o	A	D	σ	Remarks
1	178.5	77° 33'	+47° 18'	-0° 21'	Cyg XR-1
2	205.1	331 03	+64 29	-2 54	Sgr XR-2 (resolved as two sources)
3	208.2	320 52	+60 26	+3 18	Sgr XR-2
4	211.0	313 45	+56 15	+2 00 +0 54	Oph XR-1 SN 1604 (not the source)
5	212.6	310 22	+53 42	-0 24 -1 14	Sgr XR-1 Galactic center (not the source)
6	218.3	300 54	+43 51	+0 24	Sco XR-2
7	220.8	297 41	+39 16	+0 03	Sco XR-3

TABLE 3

TOTAL COUNTS OBSERVED FROM SCANS OF THE BRIGHTEST SCORPIUS SOURCE

Detector	Nominal Energy Interval (keV)	Observed Count		
		Scan 2	Scan 3	Scan 4
C	2-4	-	< 40	< 40
	4-8	1006 ± 34	4055 ± 67	3753 ± 64
	8-12	142 ± 15	540 ± 30	523 ± 29
	12-20	-	100 ± 50	100 ± 50
B	0.5-6.	-	150 ± 25	170 ± 25

TABLE 4

COMPARISON OF MEASURED FLUXES OF THE REPORTED X-RAY SOURCES

This work (uncorrected)			1964 Survey of the Naval Research Laboratory*		Ratio of counts cm^{-2} sec^{-1}
Time from launch (sec)	4-8-keV counts cm^{-2} sec^{-1}	Assumed θ	Source	counts cm^{-2} sec^{-1}	$\left(\frac{\text{This work corrected}}{\text{NRL}}\right)$
178.5	0.73	2^{o}	Cyg XR-1	3.6	0.2
205.1	0.86	1	Sgr XR-2	1.5	1.1
208.2	0.80				
211.0	1.39	8	Oph XR-1	1.3	1.5
212.6	0.86	1	Sgr XR-1	1.6	0.6
218.3	0.66	7	Sco XR-2	1.4	0.7
220.8	1.09	0	Sco XR-3	1.1	0.9
-	11.0	0	Sco XR-1	18.7	0.6**

* Bowyer et al. (1965)

** A similar comparison to the data of Giacconi et al. (1964) yields a ratio of 0.9 for Sco XR-1; beryllium window counters were used for both of the measurements.

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FIGURE CAPTIONS

1. A plot in galactic coordinates showing the region of sky selected for observation by rocket-borne X-ray detectors. These detectors had three differently oriented fields of view as is shown schematically by the rectangular outlines designated T, C, and B near the left or northern horizon. The center of each detector's field of view moved along the indicated scan lines as the rocket rolled. The shaded areas indicate the zones of sky scanned by detector C and show, in the upper right of the figure, the three scans over the brightest Scorpius source.

2. This portion of the telemetered record indicates the information obtained for the Scorpius source on scan 3. Data relevant to the T, C, and B X-ray detectors, to two optical starlight sensors designated photometers M and V, and to the operation of the ACS roll jet are given.

3a. Variation of counter sensitivity with photon energy is shown here for counters having two different entrance window materials. The abrupt decrease at 1.5 keV in the aluminum-window counter efficiency is due to the K-absorption discontinuity of the aluminum window. The abrupt rise in each curve at 3.2 keV is due to the K-absorption discontinuity of the counters' argon gas.

3b. The sensitivity indicated above is that for detecting a given energy photon in each of the four nominally defined (2-4-keV, 4-8-keV, 8-12-keV, and 12-20-keV) energy intervals of detector C.

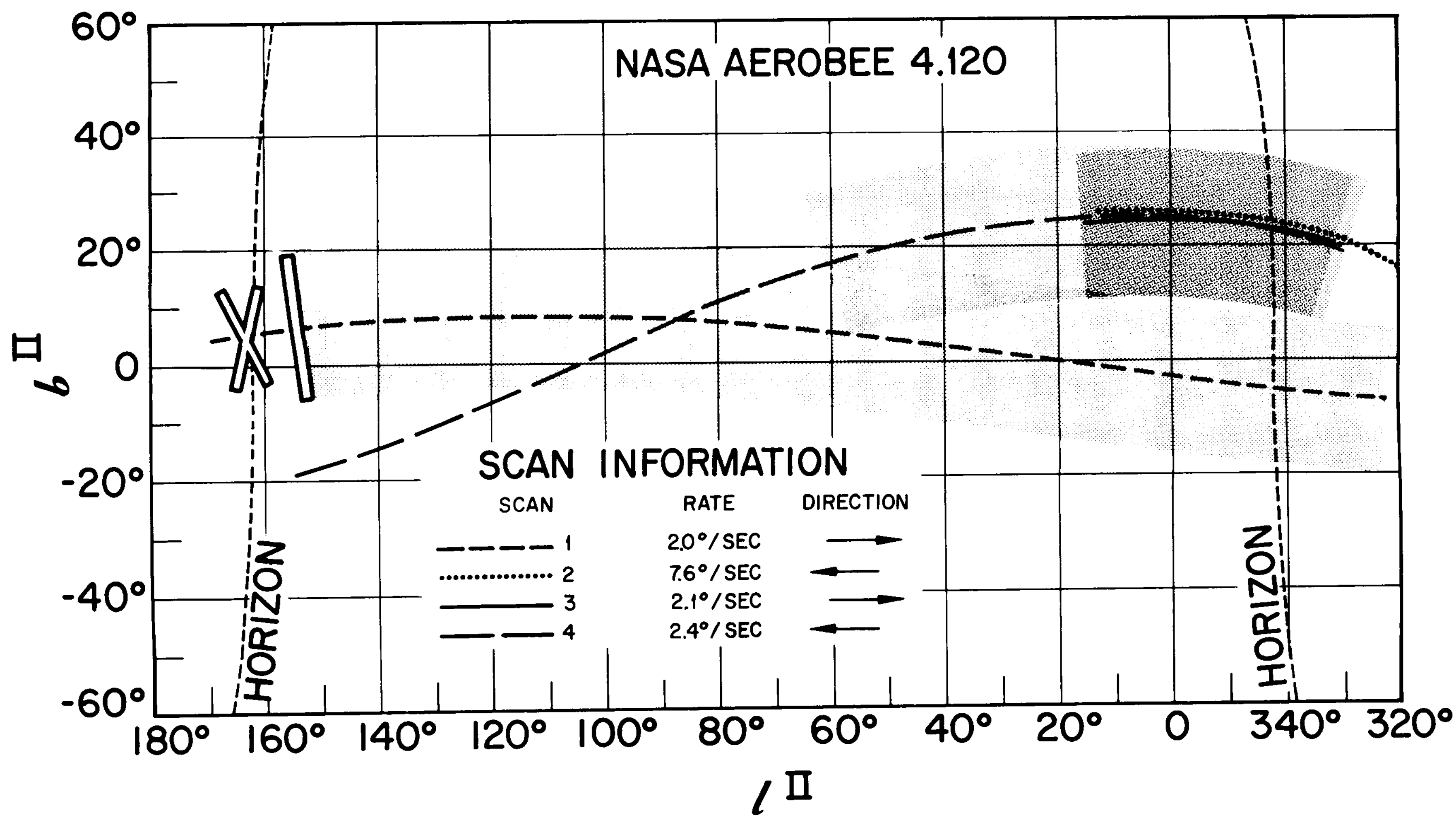
4. Graphs of various data as a function of seconds of time from launch. The count of pulses in the 4-8-keV channel of detector C is

given in part a for the portion of the flight shown in Figure 1; the zenith angle Z and atmospheric transmission T, for 6 keV photons, are also shown. Part b contains the variation of X-ray flux in two energy intervals as detector C observed the Cyg XR-1 source during scan 1. Part c indicates the aggregate of incompletely resolved X-ray sources lying in the general direction of the galactic center; the difference between the solid and dotted lines near 212 sec corresponds to counts from the brightest source in Scorpius, which was 25° off the collimator centerline at this time.

5. Maps of the sky adapted from Becvar's Atlas of the Heavens. The dashed lines indicate the paths of the collimator axis. The narrow dimension of the rectangular region corresponds to the $\pm$ 15' position error in observing the source, while the NRL results are indicated by $1\overset{\circ}{.}5$ radius circles. Part a shows the Cyg XR-1 region; the long dimension of the rectangle gives the maximum extent of the field of view. Part b shows the region near the galactic center.

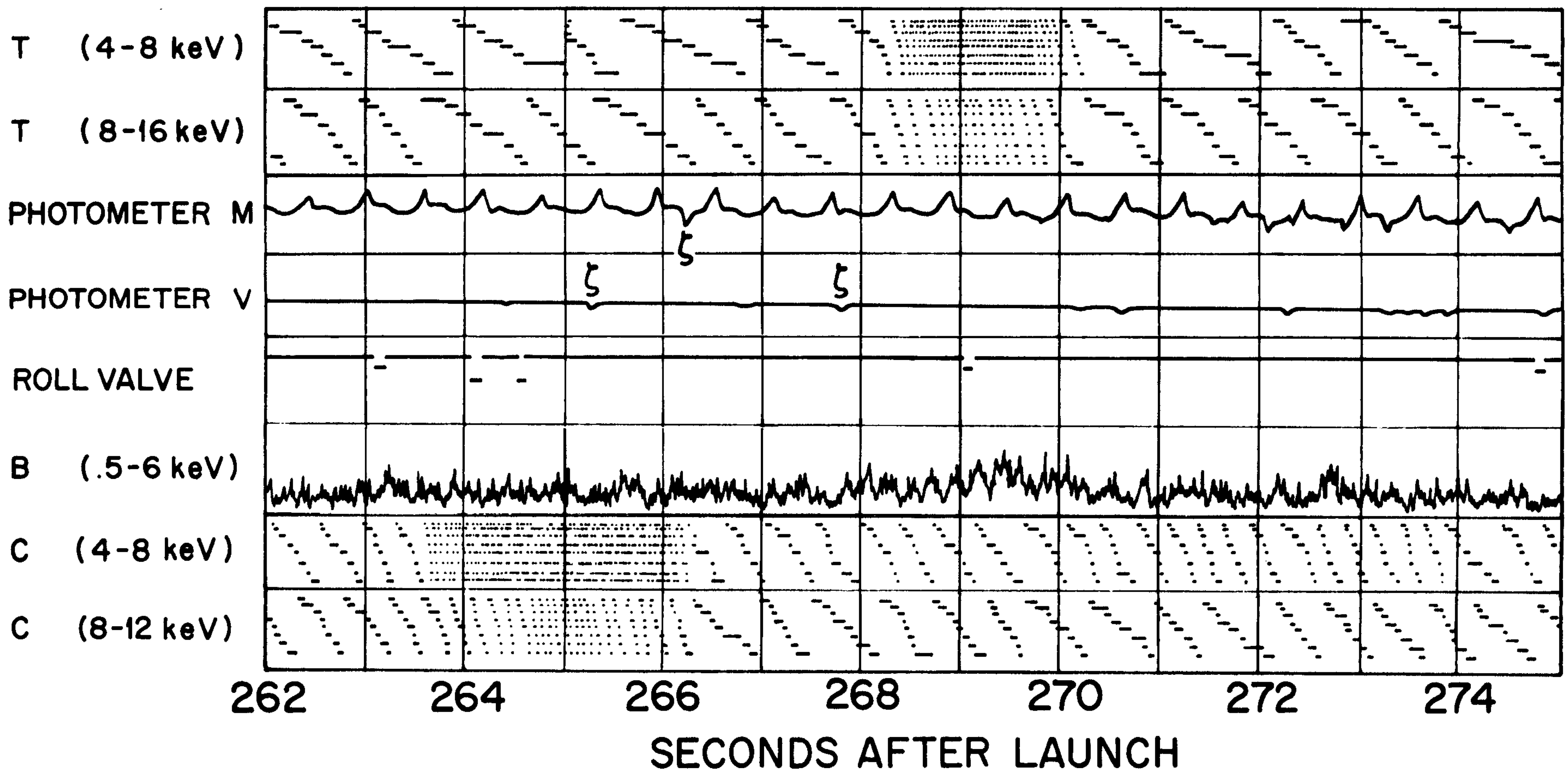
6. Variation in count rate with time in three energy intervals as observed on scan 3 over Sco XR-1. The background in the 12-20-keV interval is not well established and is drawn in rather arbitrarily.

7. Relative counts per unit energy for Sco XR-1 (Table 3), corrected for counter efficiency (Figure 3b). The lowest-energy datum represents a poorly defined upper limit.



NASA AEROBEE 4.120
SCAN INFORMATION
SCAN
RATE
DIRECTION
1
2.0°/SEC
2
7.6°/SEC
3
2.1°/SEC
4
2.4°/SEC
HORIZON
HORIZON
60°
40°
20°
0
-20°
-40°
-60°
180°
160°
140°
120°
100°
80°
60°
40°
20°
0
340°
320°
b^{II}
l^{II}

Figure 1



T (4-8 keV)
T (8-16 keV)
PHOTOMETER M
PHOTOMETER V
ROLL VALVE
B (.5-6 keV)
C (4-8 keV)
C (8-12 keV)
ζ
ζ
ζ
262
264
266
268
270
272
274
SECONDS AFTER LAUNCH

Figure 2

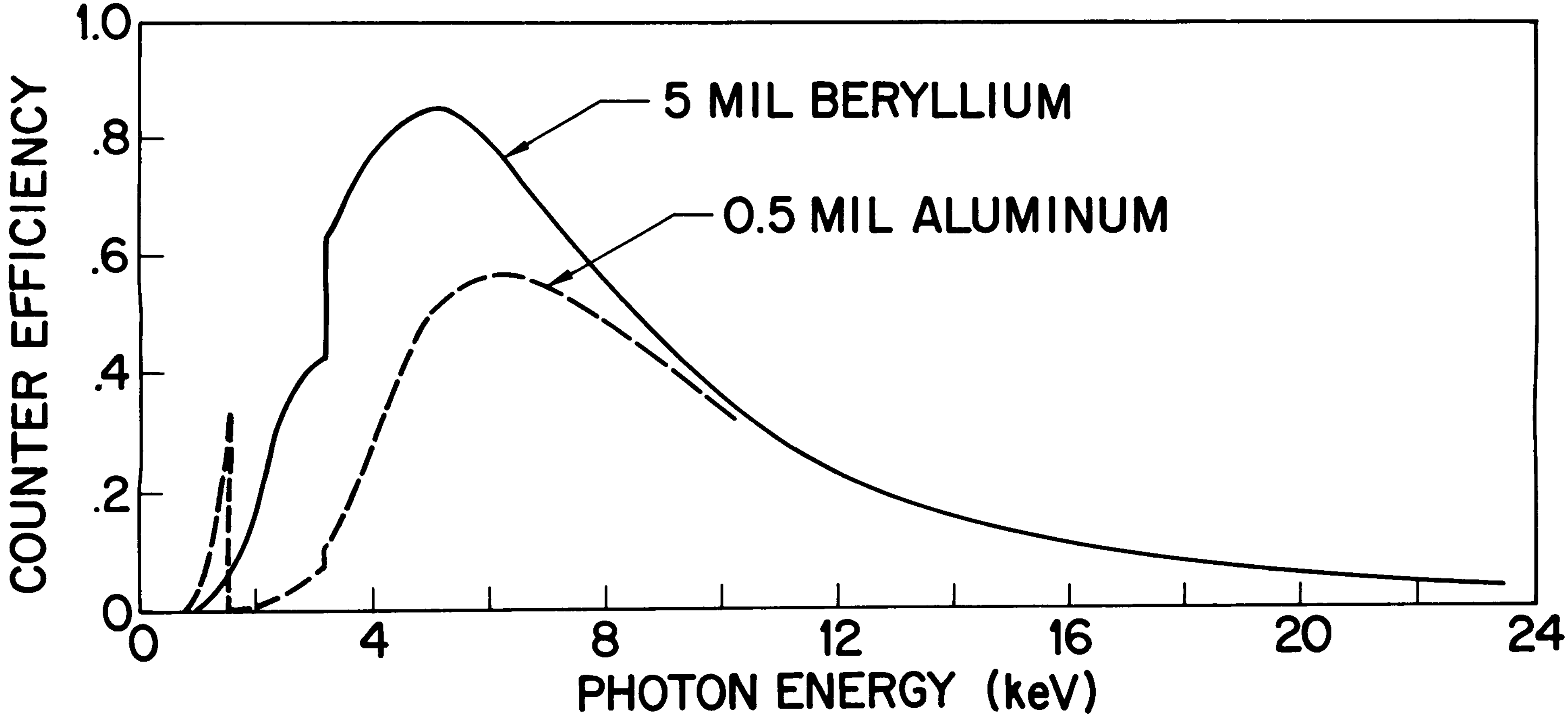

5 MIL BERYLLIUM
0.5 MIL ALUMINUM
COUNTER EFFICIENCY
1.0
.8
.6
.4
.2
0
0
4
8
12
16
20
24
PHOTON ENERGY (keV)

Figure 3a

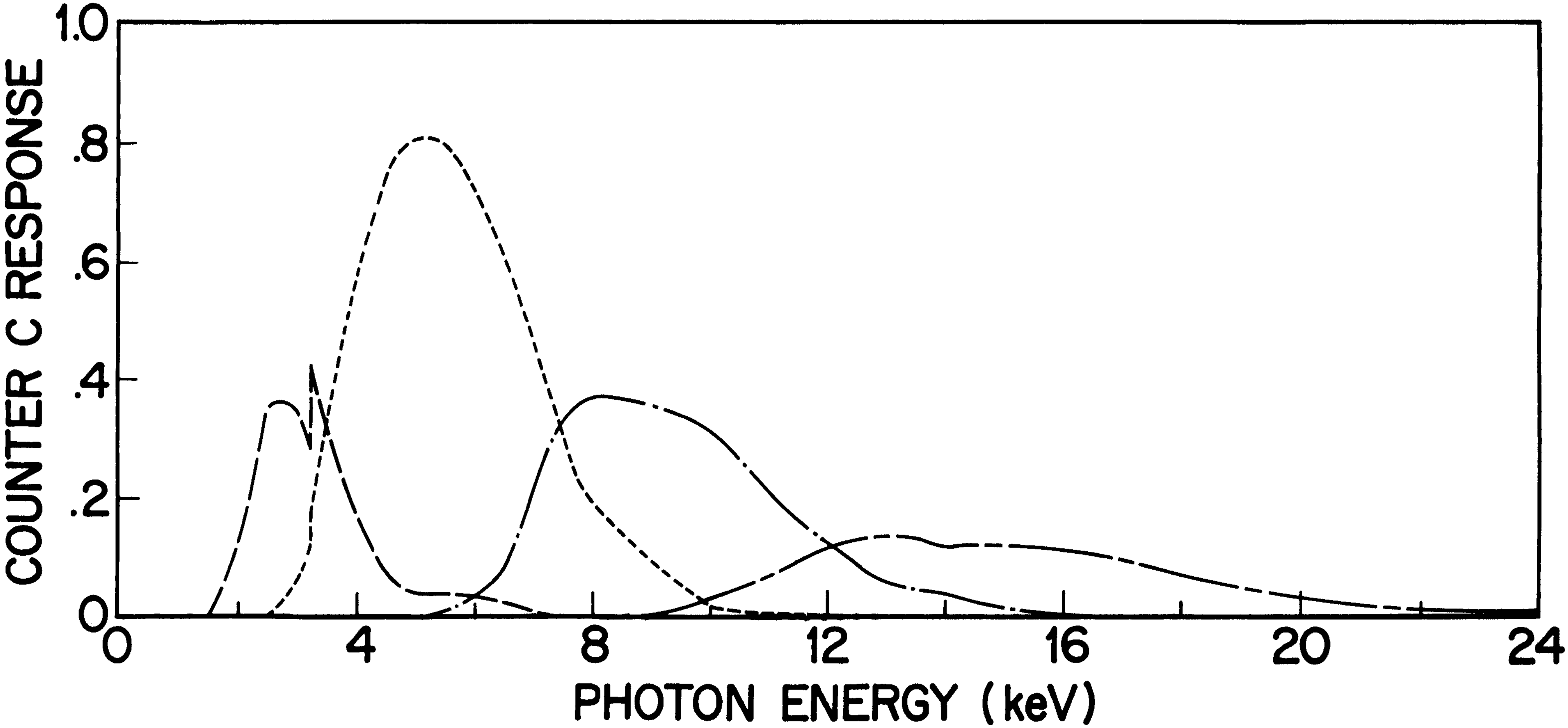


Figure 3b

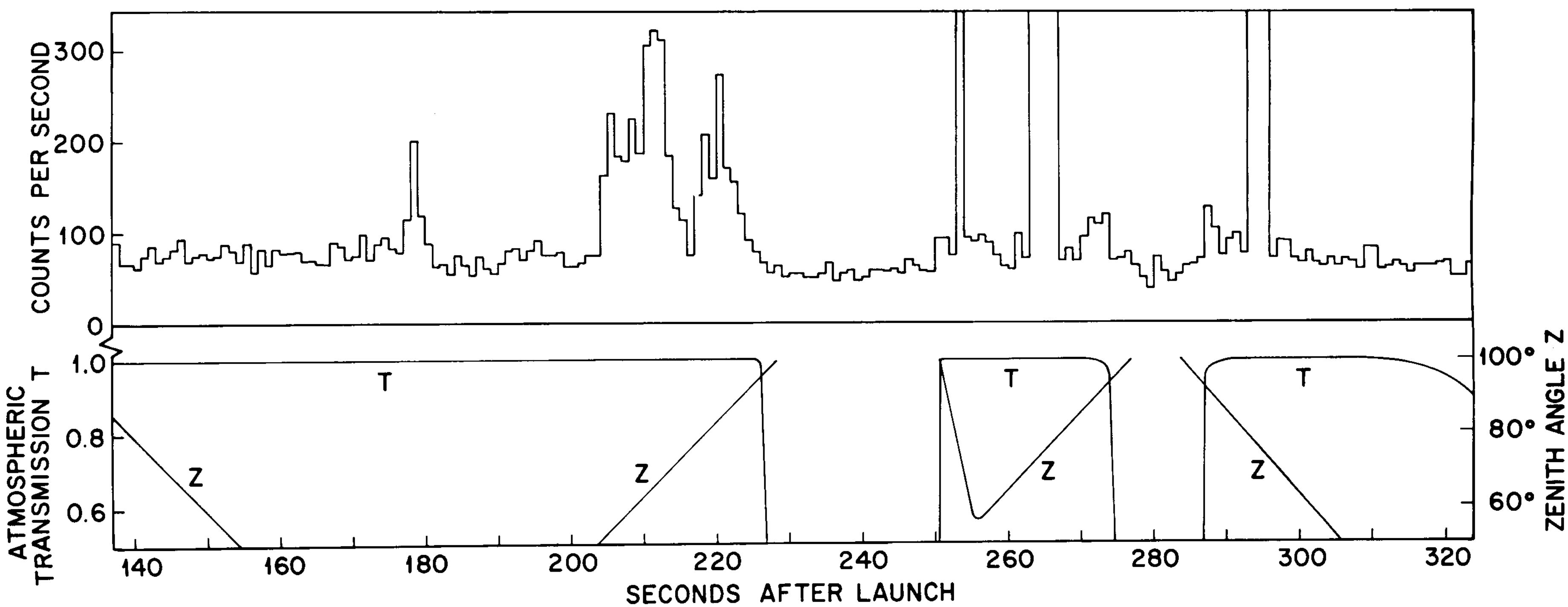

COUNTS PER SECOND
300
200
100
0
ATMOSPHERIC TRANSMISSION T
1.0
0.8
0.6
T
Z
ZENITH ANGLE Z
100°
80°
60°
140
160
180
200
220
240
260
280
300
320
SECONDS AFTER LAUNCH

Figure 4a

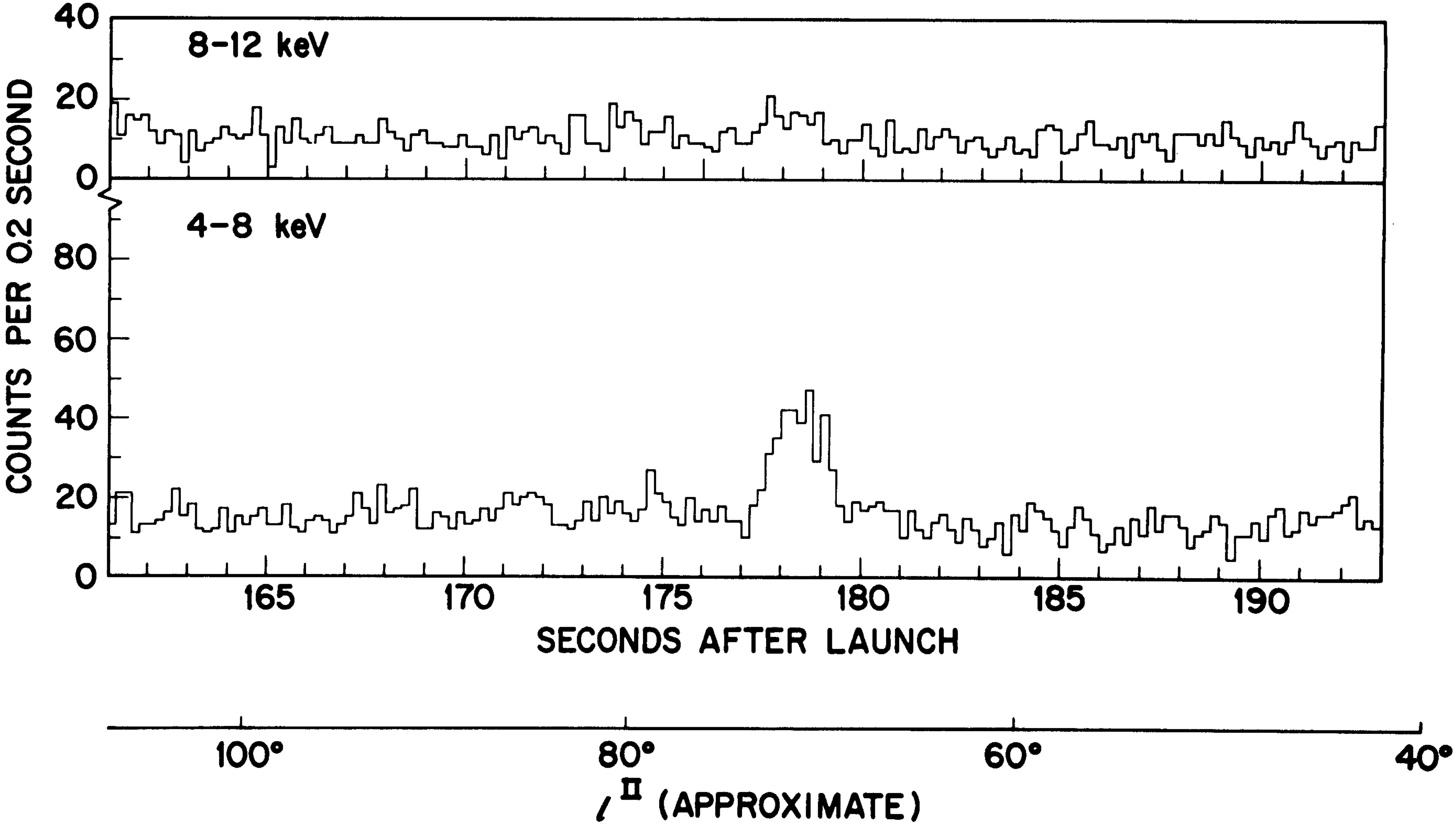
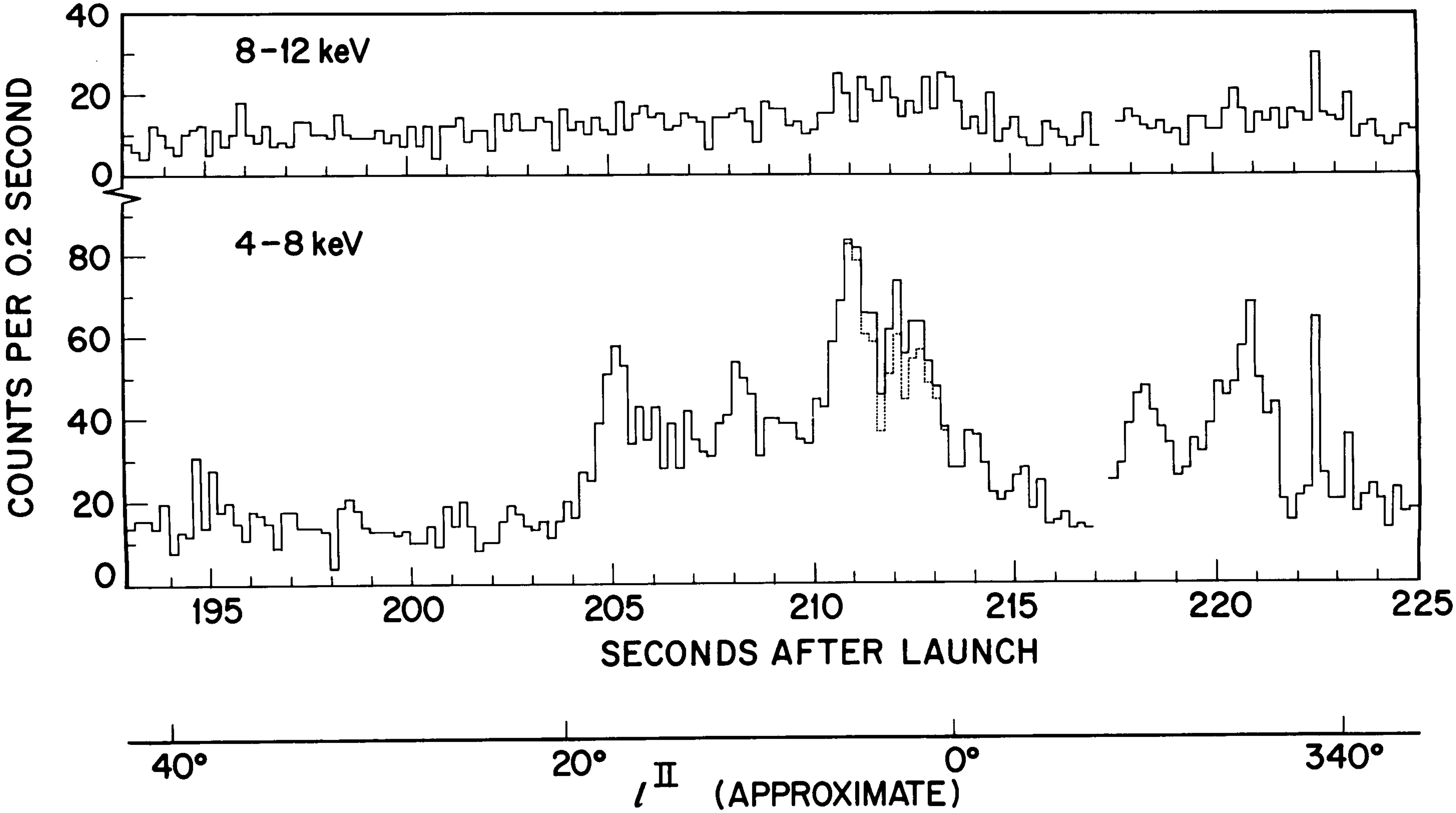
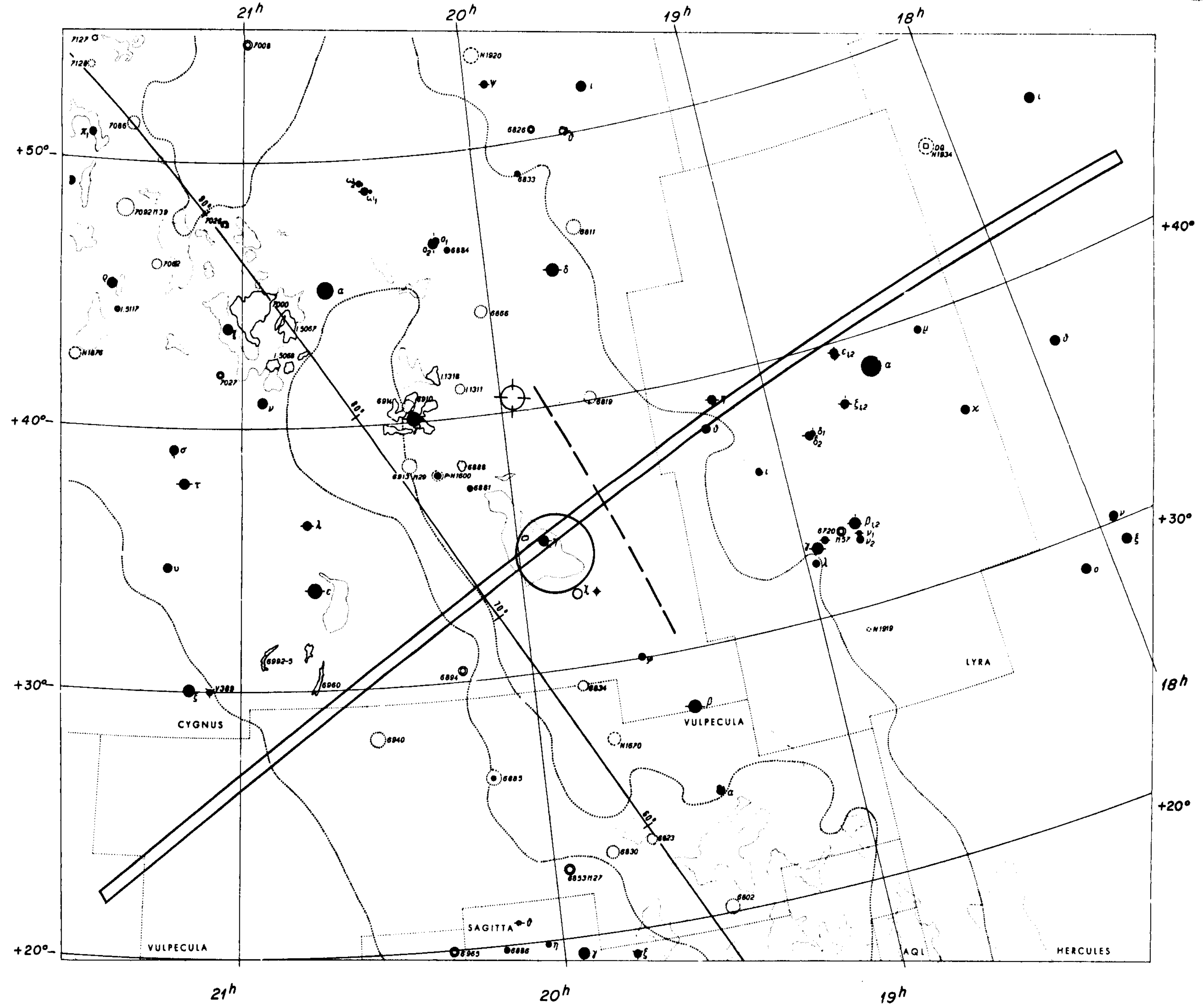

8-12 keV
4-8 keV
COUNTS PER 0.2 SECOND
40
20
0
80
60
40
20
0
165
170
175
180
185
190
SECONDS AFTER LAUNCH
100°
80°
60°
40°
l^{II} (APPROXIMATE)

Figure 4b



8-12 keV
4-8 keV
COUNTS PER 0.2 SECOND
40
20
0
80
60
40
20
0
195
200
205
210
215
220
225
SECONDS AFTER LAUNCH
40°
20°
0°
340°
l^{II} (APPROXIMATE)

Figure 4c



21h
20h
19h
18h
+50°
+40°
+30°
+20°
CYGNUS
VULPECULA
LYRA
SAGITTA
AQL
HERCULES

Figure 5a

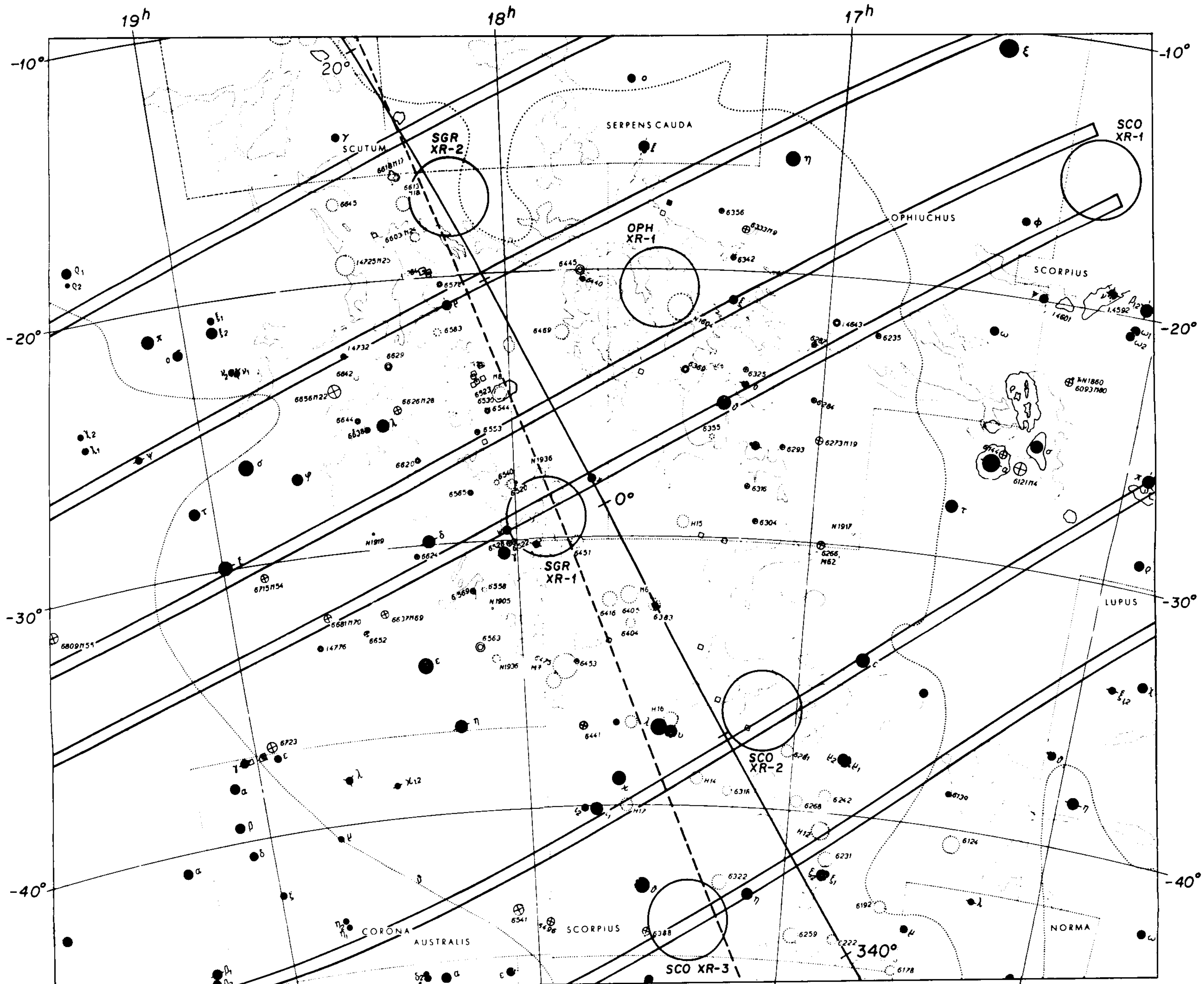

19h
18h
17h
16h
-10°
-20°
-30°
-40°
SCO XR-1
SCO XR-2
SCO XR-3
SGR XR-1
SGR XR-2
OPH XR-1
SERPENS CAUDA
SCUTUM
OPHIUCHUS
SCORPIUS
LUPUS
NORMA
CORONA AUSTRALIS
0°
20°
340°

Figure 5b

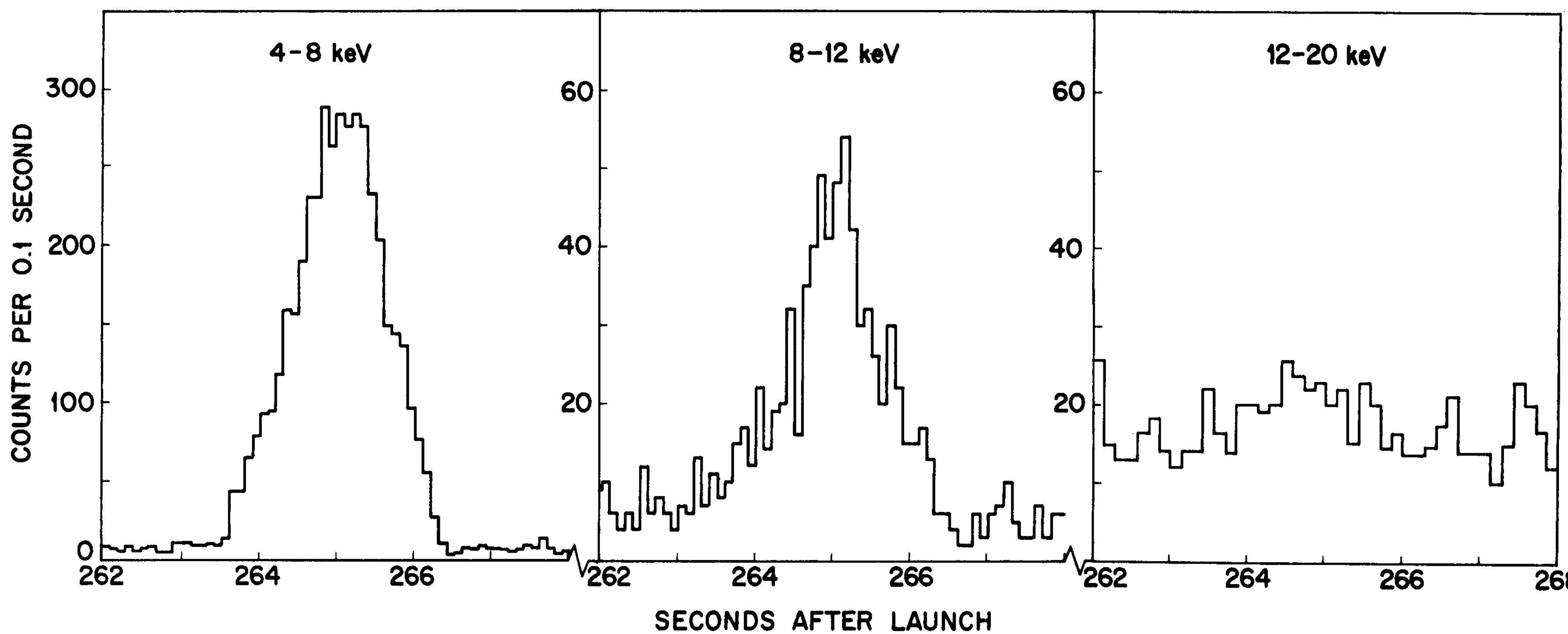

4-8 keV
8-12 keV
12-20 keV
300
200
100
0
60
40
20
60
40
20
COUNTS PER 0.1 SECOND
262
264
266
262
264
266
262
264
266
268
SECONDS AFTER LAUNCH

Figure 6

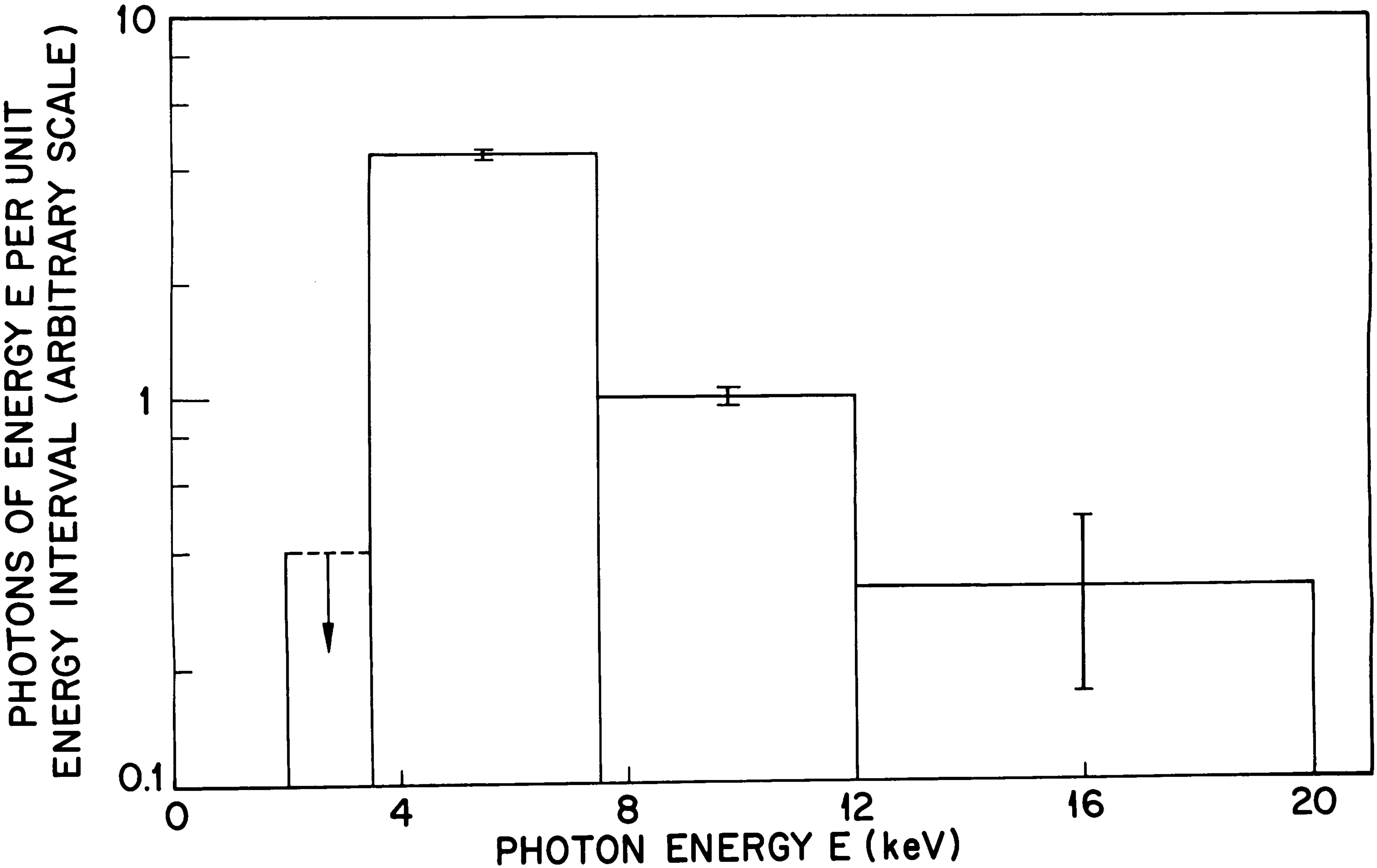

PHOTONS OF ENERGY E PER UNIT ENERGY INTERVAL (ARBITRARY SCALE)
10
1
0.1
0
4
8
12
16
20
PHOTON ENERGY E (keV)

Figure 7